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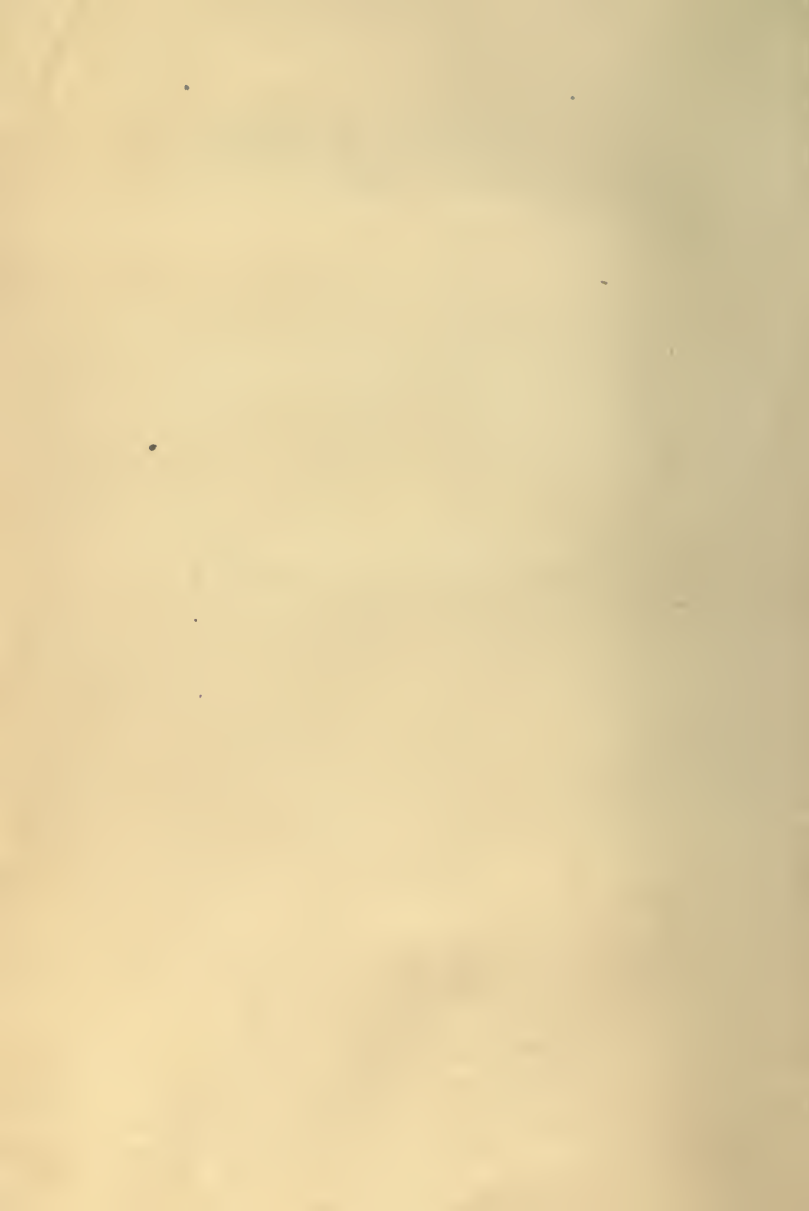
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MILITARY TOPOGRAPHY

*ILLUSTRATED BY PRACTICAL EXAMPLES
OF A PRACTICAL SUBJECT*

BY

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WILLIAM BLACKWOOD AND SONS
EDINBURGH AND LONDON
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INTRODUCTION.

THE following exercises are intended to assist beginners in Military Topography to overcome the difficulty they constantly meet with on finding that the study of a most practical and out-of-doors subject is conducted at a table in a class-room, and that the ground, its slopes, its features, its hills, its valleys, and its streams, which they are told to depict, disappear in a mass of rules and formulæ. In each of these exercises the student is introduced to a small portion of the ground, is given just so many data as will assist him to understand its features, and sufficient points to enable him to sketch it correctly. Each example is intended as a practical guide to some rule or formula, and to point out its use to the sketcher when on the actual ground.

In the theoretical or indoor study of Military Topography a frequent cause of perplexity with beginners is to mix up the scale of the plan with

the slopes of the ground, and it is not always easy to convince them that there is no connection between the two. No matter what the scale of our plan is the hard-and-fast mathematical truth remains that if we set out to pace down a slope of 1° , we shall have to take fifty-seven paces before we are one pace lower than our starting-point, and that if the slope changes to 2° or 3° , we shall have to complete one-half or one-third of the same fifty-seven paces before we have got down our one pace.

The difficulty, no doubt, is owing to the use of the "normal system," in which the distance to be measured vertically between contours varies with the scale. To a man who has once mastered the subject, of course, no such difficulty can occur; it is only with beginners it is possible, and it is mentioned here because these examples are intended for their benefit.

It is also a trouble to beginners to find themselves so often face to face with that perfectly intractable 19.1, which appears to have jostled the original 57.3 out of place. We know the change is made to save figures, but it is at the expense of sacrificing unity. True, we shall walk down our 1° slope for 19.1 yards before we shall find ourselves one foot below our starting-point, and the figures and the reason for their adoption are clear enough to the ordinary surveyor; but I have found that the original rule has far more hold on the student's mind, and that

all difficulty is at an end when he is taught that in order to drop one unit vertically he must measure fifty-seven units horizontally down a slope of 1° .

In working out these examples do not be in a hurry, do not try to make a pretty picture and get the thing done; in each example is wrapped up the application of one or more standard rules or formulæ which it is important to learn and to understand. Above everything accuracy must not be sacrificed to pictorial effect; when the sketch is inspected the dividers will be applied to the various distances shown, and marks of approval will be in proportion to the difference between those on the sketch and those on the original.

Another hint. Look out for your triangles! Remember that the solution of most of the problems in Military Topography depends upon that of a right-angled triangle. First find out your triangle—not always easy—and this found look out which of the sides are given, and if there are two such, the third, representing the x of the puzzle, is easily forthcoming.

Again, when following “section lines,” or traverses in which changes of height occur, mark each change in order by the formula, by which the exact vertical height is found and a secure starting-point is gained for further progress. Do not be content to step the slopes up or down with the scale of horizontal equivalents on your protractor, that is well enough

for adepts, or for rough out-of-door work when no examiner with his dividers will have the last word in the matter.

In the following examples, those in Part I. deal with elementary problems in intersection, resection, the use of the formulæ to ascertain heights and distances, and plotting easy ground. Those in Part II. show how to plot the notes jotted down in the field-book, more especially when taken across uneven ground: the ordinary field-book problems are not given here as those in the text-books are always available. In Part III. "form lines" and "section lines" are worked out and their use fully explained. Part IV. takes the learner on to more advanced ground, the sketches being framed to include in each example most of the foregoing rules. Lastly, in Part V. two examples of sections are given, which are quite simple, but require considerable care to render with accuracy.

The plans have been executed as they would have been had they been finished in the field, sufficient accuracy only being aimed at to enable the officer requiring them to read the configurations of the ground represented for military purposes.

W. E. MONTAGUE.

PART I.

ELEMENTARY.

I.

A, B, C, are hill-tops overlooking a lake which lies in their centre, and bearing from that central point respectively 15° , 135° , 255° .

Their summits are respectively 70 ft., 130 ft., 90 ft. above datum level; the lake being 30 ft. above the same point.

Slopes taken to each hill-top from the lake are $1\frac{1}{2}^\circ$, 4° , 2° respectively.

Plot the above. Scale $\frac{1}{10550}$, normal contours.

II.

A is a hill-top 100 ft. above datum level.

B and C are under-features on a spur stretching S. from the main hill. A distance of 500 yds.

between A and B, and B and C; each under-feature is 40 ft. lower than the hill to the N. of it.

D is another under-feature of the same height as B; from it bearings were taken to B 300° , to C 240° .

The col between A and B is 65 ft. below A; those between B and C, and B and D, 45 ft. below B.

Plot the above at 6 in. to the mile, normal contours.

III.

A stream winds through a valley in a direction bearing 215° for a distance of 1000 yds., its average fall $\frac{1}{30}$.

A, B, C, are hill-tops on either side.

From the head of the stream the bearing of A is 245° , the angle of elevation 4° , slope concave; and from the mouth of the stream it bears 357° , the bearing of C being 60° .

From A the bearing of C is 120° .

From C the bearing of B is 33° .

The angle of elevation of B from the head of the stream is 4° .

C and B are each 40 ft. higher than the head of the stream.

The col between B and C is 55 ft. above sea-level.

Plot the above at 6 in. to the mile, normal contours.

IV.

A stream rises in a valley at a point 60 ft. above the sea, into which it flows in a direction due S.

A and B are hill-tops W. and E. of the source of the stream, each 250 yds. distant from it, A being 40 ft. lower than B.

The angle of depression from A to the sea, 670 yds. distant, is 4° .

From B a spur stretches southwards to the coast ; on it two under-features, connected by cols C and D, each one 40 ft. lower than the one to the N. The angle of depression from B to them 3° .

Plot the above at 6 in. to 1 mile, contours normal.

V.

A is a hill-top which sends a spur due S. to the sea.

B is an under-feature on it, distant from A 382 yds., and 60 ft. above the sea-level.

The angle of elevation from B to A is 3° .

The col which connects B with the main hill is 36 ft. below, and 180 yds. N. of B.

Contour the above, scale 12 in. to 1 mile, vertical intervals 12 ft.

VI.

A, B, C are hill-tops.

Two streams rise midway between A and C, and A and B, uniting at a point D, 300 yds. S. of A, and continue in that direction at a fall of $\frac{1}{10}$.

Bearings from—

A to B, 155° .

A " C, 222° .

B " C, through D, 280° .

Angles of elevation—

D to A, 6° .

D " B, 6° .

D " C, 4° .

The heads of the streams are 30 ft. below B and C.

Contour the above at 12 in. to the mile, contours normal.

VII.

From the extremity of a cape projecting into the sea you pace due N. up a slope of 2° for a distance of 300 yds. to a small plateau 50 yds. across. You continue to pace down the northern slope of this knoll, still going N., the angle of depression the same as before, for 143 yds., and continue in the same direction on level ground till the hills A and

B bear E. and W. of your position ; the angle of elevation to A being 4° , to B 6° ; the latter is marked on the Ordnance map as 60 ft. above sea-level.

From the centre of the knoll bearings were taken, to A 30° , to B 327° .

Plot the above, scale 12 in. to the mile, normal contours.

VIII.

Being desirous to plot and contour an isolated hill you proceed to the summit, which is formed by a plateau stretching 300 yds. N. and S., and 150 yds. E. and W. The edge of this plateau you take as your initial contour, and from a central point on it lay out "section lines" A, B, C, bearing respectively 40° , 160° , 280° .

You then pace down each as follows :—

Line A,	{	238 yds. at 6° slope.		
		478	"	3° "
" B,	{	266	"	5° "
		382	"	4° "
" C,	{	191	"	3° "
		716	"	2° "
		860	"	1° "

Plot in the above, scale 4 in. to 1 mile, normal contours.

IX.

The summit of an island 100 ft. above the sea forms a plateau about 350 yds. across, the S.E. edge broken inwards by the head of a valley in which is a stream which joins the sea at an average fall of $\frac{1}{16}$.

An under-feature, 20 ft. below the summit and connected with the main hill by a col 45 ft. above sea-level, bears from a central point on the plateau 157° , the angle of depression to it 1° . Slopes on the E. of the main hill $2\frac{1}{2}^\circ$, on the N. and W. 10° .

Plot the above at 6 in. to a mile, normal contours.

X.

A and B are hill-tops on an island.

C and D are under-features.

Bearings from—

A to B, 107° ; distance, 500 yds.

A " C, 68° .

B " D, 135° ; " 760 "

B " C, 2° .

The sea is—

1200 yds. S. of B.

190 " " D.

400 " W. of A.

200 " N. of C.

The col between A and B is 230 yds. distant from and 70 ft. below the former.

Angles of depression from—

B to D, 3° .

A " B, 1° .

B " C, 3° .

D " the sea, 7° .

Plot the above at 6 in. to a mile, normal contours.

PART II.

THE FIELD-BOOK.

XI.

The following traverse was taken across some low hills; plot and contour a plan from the entries, scale $\frac{1}{10500}$, normal contours:—

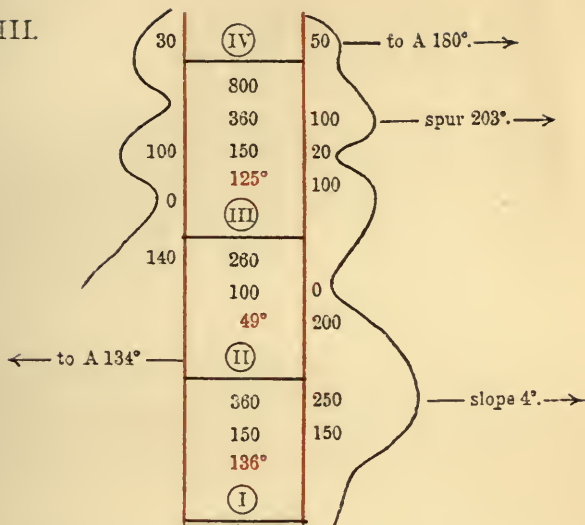
Forward angle A to B 60°.	Forward angle B to C 300°.	Forward angle C to D 180°.
Yds.	Yds.	Yds.
Rise 6° . for 320	Level . for 50	Level . for 50
Level . " 100	Fall 4° . " 190	Fall 4° . " 95
Fall 5° . " 228	Level . " 20	Level . " 20
Level . " 20	Rise 2° . " 191	Rise 4° . " 285
Rise 5° . " 152	Level . " 50	Level . " 50
Level . " 50		

XII.

628	Fall 9°; closing angle on (I.) 270°.
481	Level.
441	Rise 2°.
299	Fall 3°.
75	Level.
180°	
(III)	
330	Level.
310	Rise 8°.
238	Level.
198	Level; stream's source, fall $\frac{1}{2}$ °.
158	Fall 7°.
50	Level.
90°	
(II)	
628	Level.
528	Rise 7°.
447	Rise 5°.
333	Rise 3°.
237	Rise 2°.
95	Rise 2°; stream 150 yds. 90°. —→
360°	
(I.)	

Plot the above entries in a field-book; scale 12 inches to 1 mile, normal contours.

XIII.



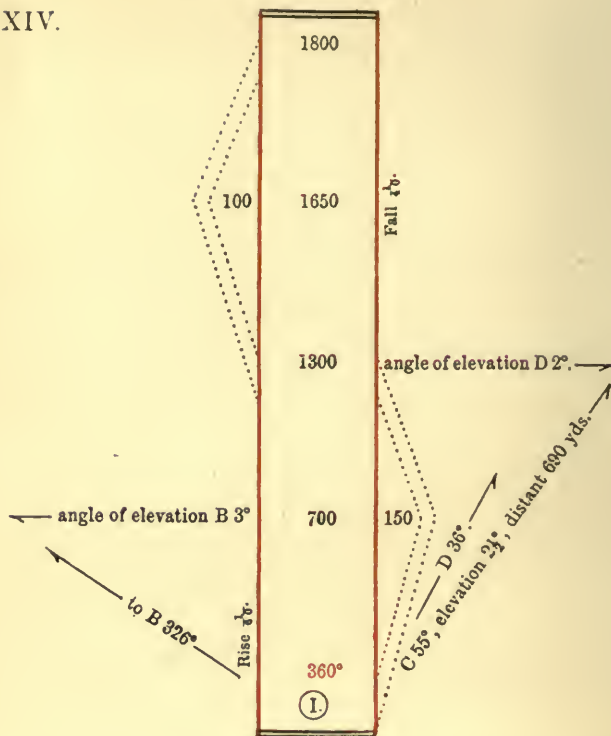
A tract of hilly country three-quarters of a mile square is to be represented on a plan three inches square.

The features are a plateau and a ridge stretching from it, both 250 feet above datum level; an under-feature, A, connected with the main hill by a col, a spur, and a valley in which is a stream. Angle of depression from the extremity of the ridge to A $2\frac{1}{2}^\circ$, to the col 320 yds. distant, 6° .

The above traverse was made of the plateau and ridge commencing in the N.W. corner of the ground.

Sketch the above to scale, normal contours.

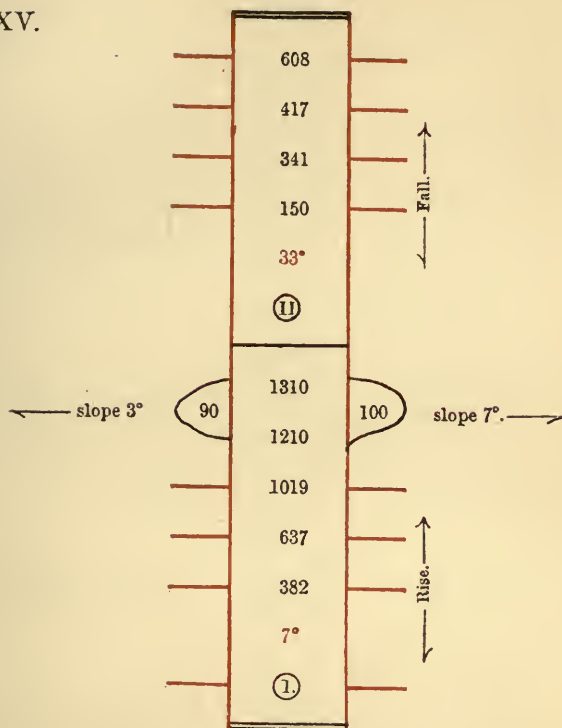
XIV.



Plot the above traverse of an unenclosed road winding through a valley between B, C, D, hill-tops, from sea-coast to sea-coast, the highest point upon it 45 feet above the sea. B is 20 feet higher than C, and D is 10 feet higher than B.

Scale 6 inches to the mile, normal contours.

XV.

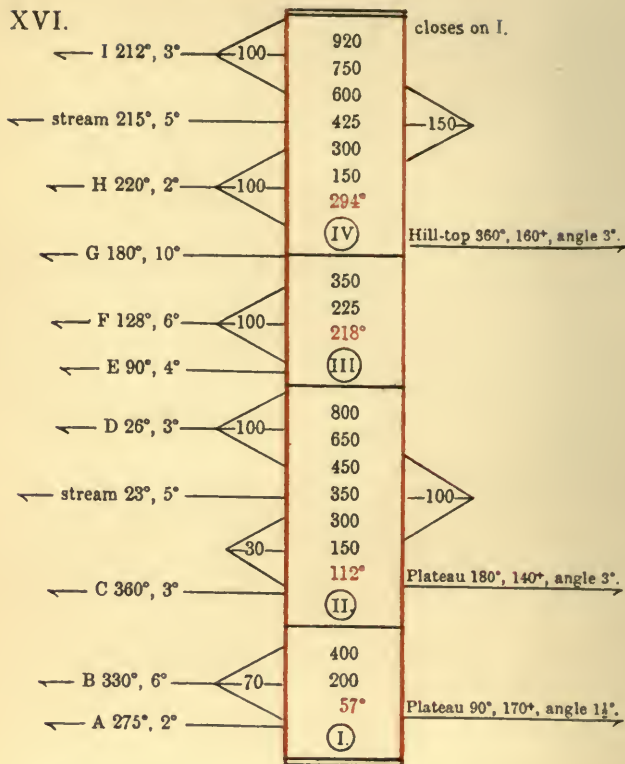


Plot the above traverse of a footpath crossing an isolated hill. Scale $\frac{1}{10500}$, normal contours.

What are the angles of the slope between the contours?

What is the general gradient of the path in going up and coming down the hill?

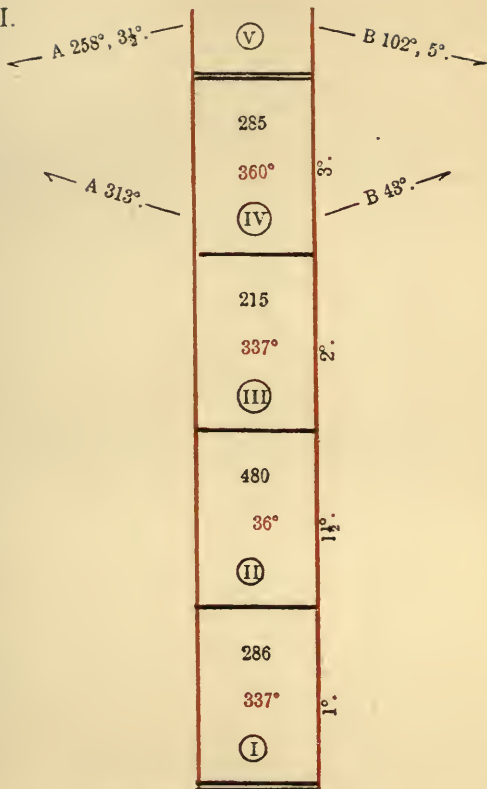
XVI.



Plot and contour the above notes in a field-book of an isolated hill 125 feet above datum level. The traverse shown is that of the initial contour, 100 feet above datum.

Scale $\frac{1}{10580}$, VI. 20 feet.

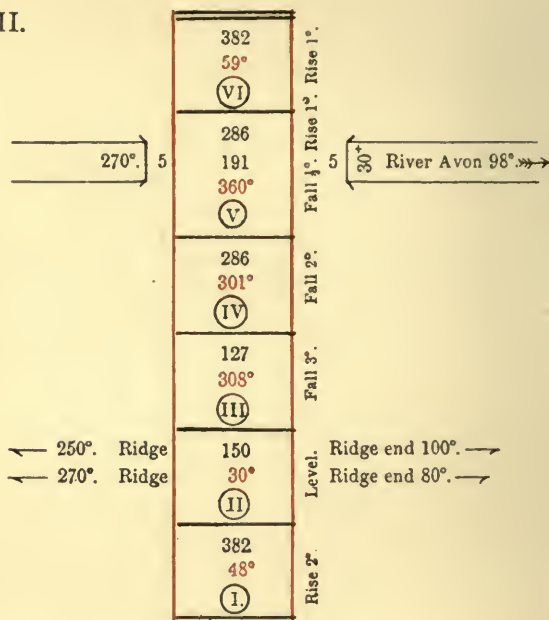
XVII.



Plot and contour the above entries in a field-book of a road winding up a valley to a pass between two hill-tops.

Scale 12 inches to 1 mile, VI. 15 feet.

XVIII.



Plot and contour the above notes from a field-book of a road crossing a ridge, descending a valley, and rising the opposite hillside.

Slopes of the ridge, on the South 3°.

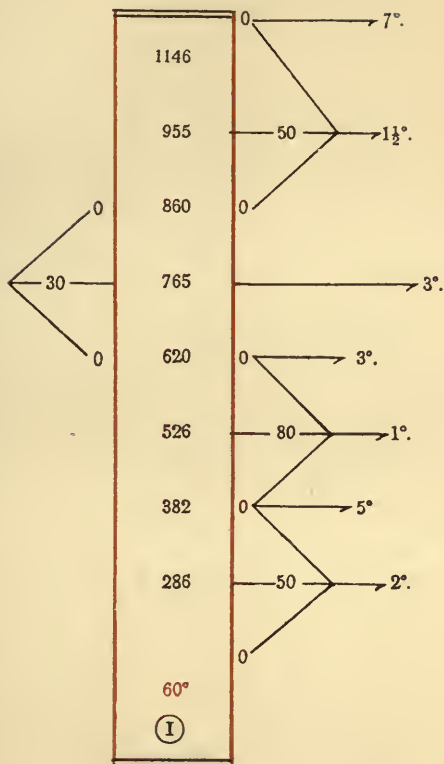
" " North 5° for 76 yards,
then 4°.

" " East 5°.

Slope of the hillside North of the river 2°.

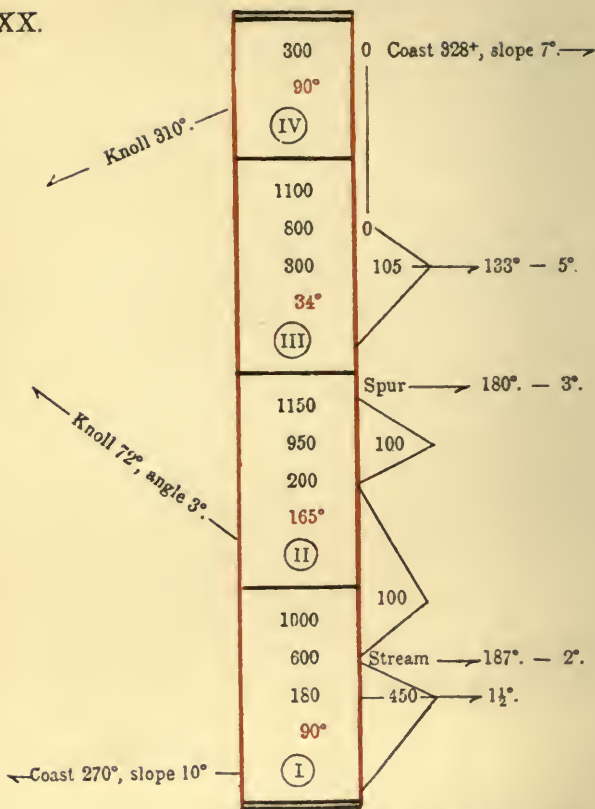
Scale $\frac{1}{10500}$, normal contours.

XIX.



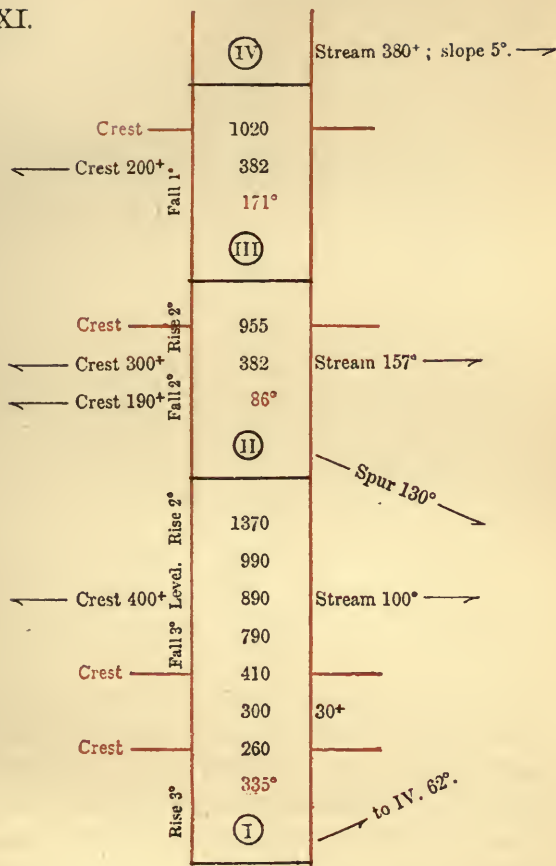
Plot the above entries in a field-book of the traverse of a road winding from the coast up the side of a hill, general slope 1°, and put in the contours at 10 ft. vertical interval on the right of the road; normal scale.

XX.



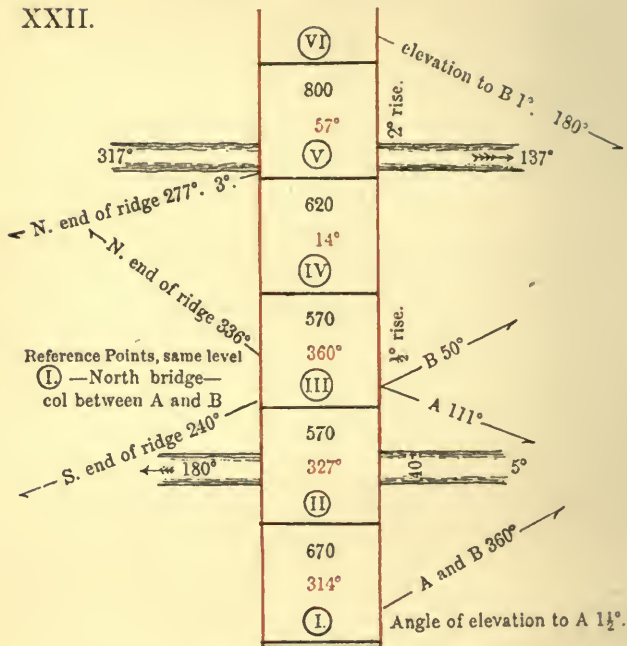
Plot the above entries in a field-book of the initial contour of a hill overlooking the sea, and fill in the contours to the sea-level on the south; scale 4 inches to 1 mile, normal contours.

XXI.



Plot the above entries in a field-book of a valley-head; scale 6 inches to 1 mile, normal contours.

XXII.



Plot the above entries in a field-book of a traverse line up a valley enclosed on the east by A and B, hill-tops, on the west by a long ridge. A river flows through the valley, its average fall 1°, crossed by a bridge about 600 yds. from its mouth, and by another higher up. The traverse follows an unfenced road which crosses the river at the bridges. Scale $\frac{1}{15840}$, normal contours.

PART III.

FORM LINES.

XXIII.

A, B, C are hill-tops on a ridge to the N. of and parallel with the sea-coast. Streams rise under A and in the cols on either side, and fall into the sea at the head of sandy bays.

From a point S at the head of one of these bays, here 100 yds. across, the bearing of A is 360° , distant 1020 yds.

Bearings from—

A to B, 266° ; angle of depression, 1° ; distance, 760 yds.

A to C, $78\frac{1}{2}^\circ$; angle of depression, $1\frac{1}{2}^\circ$; distance, 760 yds.

Cols between—

A and B, 420 yds. from A; slope, 5° .

A " C, 525° " " " ; " 4° .

General slopes to the sea south of B and of C, 3° and 2° respectively.

The central bay is about 600 yds. across at its entrance.

The following "section lines" were taken:—

A to F, bearing, 202° .

A to D, 190 yds.; slope, 5° .

D " E, 1050 " " 1° .

E " F on the sea, 350 yds.; slope, 3° .

A to G, bearing, 137° ; dist., 382 yds.; slope, 3° .

G to H, bearing, 164° ; $\left\{ \begin{array}{l} \text{dist., 382 yds.; slope, } 1^{\circ}. \\ \text{" 115 " " } 2^{\circ}. \end{array} \right.$

H " K on the sea, bearing, 198° ; slope, $1\frac{1}{2}^{\circ}$.

Scale, 6 in. to 1 mile, normal contours.

XXIV.

A is a hill-top 90 ft. above sea-level, and from its summit "section lines" were taken to the coast, as follows:—

A B H, bearing, 180° .—A to B, 190 yds.; slope, 3° . B to H, slope, 2° .

A D E G, bearing, 135° .—A to D, 134 yds.; slope, 6° . D to E, 82 yds.; slope, 7° . E to G, slope, 8° .

A F K, bearing, 230° .—A to F, 115 yds.; slope, 8° . F to K, slope, 10° .

Plot and contour the above under the following conditions :—

Scale of plan, 12 in. to 1 mile.

Contours at 12 ft. vertical interval.

Calculate the heights of E and F above high water.

XXV.

From the top of a spur the following section lines were taken :—

A 1.—General slope, 5° .

A 2.—A to B, 760 yds., slope, 4° . B to C—knoll, 380 yds., depression, 1° ; level, 50 yds., (300 yds., N. and S.); fall to C, 290 yds.; C to D, 380 yds., slope, 4° .

A 3.—A to B, 380 yds., slope, 2° . B to C—knoll, 255 yds., depression, $\frac{3}{4}^{\circ}$; level, 200 yds.; fall to C, 290 yds., depression 2° ; C to D, slope, $2\frac{1}{2}^{\circ}$.

A 4.—A to B, 1275 yds., slope, 3° . B to C, 380 yds., slope, 2° . C to D—knoll, 300 yds.; level, 300 yds.; fall to D, 5° for 135 yds.

A 5.—General slope, 5° for 1070 yds.

The points D are on the datum level.

Plot and contour the above, scale $\frac{1}{25120}$, normal contours.

Calculate the heights of the three knolls.

XXVI.

A, B, C are hill-tops on an island.

Bearing of B from A, 17° ; distance, 350 yds.

Bearings of A and B respectively from C, 252° , 305° .

Angle of depression from C to A, 3° ; to B, 2° .

From C a "section line" is taken due E. to the coast, as follows: C to D, 110 yds., 6° ; D to E, 180 yds., 4° ; E to F, 175 yds., 3° .

The coast-line is indented by bays stretching inland to points midway between A and B, A and C, B and C. The head of the bay between A and B is formed by a cliff 20 ft. high.

The sea is 200 yds. north of B, and 100 yds. south of A.

Slope north of C, 10° ; south of C, 8° .

Plot and contour the above at a scale of 12 in. to the mile, normal contours.

PART IV.

ADVANCED SKETCHES.

XXVII.

A stream, after winding down a valley for about 2270 yds., joins the sea; its average fall $\frac{1}{115}$; general direction, 153° .

A and C are hill-tops, B an under-feature of C.

From the mouth of the stream, A bears 292° , and from a point 40 ft. higher up 201° .

The bearings of C from A and from the stream's source are 24° and 85° .

From B the bearing of A is 240° ; of the stream's source, 309° .

The sea is 750 yds. south of A.

From A the following angles were observed with the clinometer:—to B, depression, 1° ; to a rock in

the sea marked on the chart as $1\frac{1}{2}$ mile distant, depression, 1° ; to C, elevation, 1° .

Plot and contour the above at a scale of 4 in. to the mile, normal contours.

XXVIII.

A tract of hilly country about 1800 yds. square.

A lake, about 150 yds. across, lies in the centre of three hills, A B C. A stream leaves it on the S.E., average fall, $\frac{1}{15}$.

From the centre of the lake A bears 314° , B bears 70° , C bears 225° ; and from the shore the distance to A is 900 yds., to B 800 yds., to C 1100 yds.

The angle of elevation from the lake to A is 5° , but the slope is only 3° for the first 380 yds.

A is 100 ft. higher than B, which is 175 ft. lower than C.

Between A and B, and A and C, are cols each 100 ft. higher than the lake.

Plot the above to scale so that the distance between the shore of the lake and the hill-top C shall occupy $2\frac{1}{2}$ in. on the plan. Contour the plan on the normal scale.

XXIX.

A lake, its shores irregular, thrusting themselves into the valleys between the six hills A, B, C, D, E,

F, which enclose it; cols, 25 ft. above the lake, connecting the hills one with another.

Distance from A to B, 600 yds.

<i>Bearing of</i>	<i>Depression to lake.</i>
A to B, 50°	5° from A (same level as D).
A " C, 106°	
B " C, 205°	5° " B, distant 190 yds.
C " D, 310°	10° " C (same level as B).
B " D, 255°	5° " D, distant 230 yds.
E " A, 186°	8° " E, " 190 "
E " F, 133°	6° " F, " 127 "
E " B, 98°	
F " A, 255°	

Plot and contour the above at the same scale as that of a combined survey of which it is to form a part.

On arriving on the ground you find that you have lost your note-book in which the scale was entered. You can only call to mind that it was to be contoured on the normal scale.

You are able to ascertain the position of five consecutive contours by marks left on the ground, the slope at that point being 5° , and the distance between the whole of the marks on measurement you find to be 152 yds.

XXX.

A stream rises under a hill A, which is 1250 yds. N. of an inlet of the sea into which the stream flows.

A section line from A bearing 180° gives—288 yds., 6° slope; 480 yds., 4° slope. The remaining distance to the sea, 2° slope.

B, an under-feature of A, bears from it 213° ; distance, 700 yds.; angle of depression, $2\frac{1}{2}^\circ$. The col connecting it with A is 18 ft. below B.

C is an under-feature of B, and bears from it 180° ; distance, 800 yds.; angle of depression, $1\frac{1}{2}^\circ$. The col connecting it with B is 30 ft. above the sea. From C to the coast, due S., the slope is 7° .

From A a narrow ridge runs in a direction 140° for 600 yds., when it opens out into a plateau, covered with heath, its general direction 180° for 600 yds.; it is 300 yds. across at its widest part. Slope from its southern crest to the sea, 10° .

Plot the above, scale 6 in. to 1 mile, and fill in the contours at 20 ft. vertical interval.

XXXI.

A stream flowing in a direction from N.N.W. joins the sea, having an average fall of $\frac{1}{30}$. At D, where it

enters the sea, it is 100 yds. wide, gradually narrowing to 50 yds. 300 yds. from its mouth. Here it is crossed by an iron bridge over which a road leads to the church at a gradient not exceeding 3° ; another road follows the right bank of the stream up the valley, a line of telegraph on one side of it. On the W. of the stream where it enters the sea is a small village.

The coast W. is marshy, but rises E. of the stream into cliffs 40 ft. high. The church, on a hill A, bears from D 70° ; angle of depression to D, 4° .

A is an under-feature of B, a hill which bears from D 22° ; angle of elevation, 4° . The col between A and B is 75 ft. below A.

From a point 1340 yds. up the stream the bearing of B is 94° and of A 134° .

500 yds. W. of this point is the head of another valley through which a stream flows to join the first stream at the village, average fall to D $\frac{1}{30}$, the valley-sides covered with oak-trees.

Plot the above at 6 in. to 1 mile, and fill in the contours at the normal intervals.

XXXII.

A hill A is due W. of another hill B, each 120 ft. above a small lake which lies between them.

A stream leaves the lake on the S., and continues its course due S.; its average fall $\frac{1}{80}$.

A point H on the stream marks where two smaller streams join it from the hills to the eastward, and bears from A 155° , from B 204° .

From B a spur stretches in a direction 150° ; two under-features C and D on it, connected by cols with B and with each other; a distance of 350 yds. between B and C, and C and D; angle of depression from B to both, 3° . Streams rise below these cols and join the main stream at H.

From the lake-shore the angles of elevation to A and B are 5° and 7° . The slopes of A are gentle at first, becoming steeper as they ascend.

Plot the above, scale 6 in. to 1 mile, and contour it according to the normal system.

XXXIII.

A lake, about 400 yds. E. and W. and 200 N. and S., lies in the hollow of some hills, at a height of 90 ft. above datum level.

A, B, E are hill-tops; C and D extreme points of a ridge; K a knoll, its summit circular, about 80 yds. across; F and G streams which rise under the cols on either side of B and flow into the lake. Another stream leaves the lake on its southern side at a point

M with a uniform fall of $\frac{1}{15}$, and a fourth stream quits the basin at H, flowing S.W.

M is in the direct line between D and K, 700 yds. distant from D.

Bearings from D.

C, 360° ,
distant 900 yds.

E, 256° .

K, 282° .

A, 302° .

B, 321° .

F, 314° .

G, 346° .

Bearings from A.

H, 173° .

Bearings from C.

E, 227° .

K, 239° .

A, 273° .

B, 275° .

G, 300° .

Bearings from K.

F, 2° .

H, 240° .

Angles of elevation.

K to B, 2° .

K " A, 3° .

M " E, 4° .

Angles of depression.

K to M, 2° .

D " M, 4° .

B " F, $2\frac{1}{2}^\circ$.

B " G, 2° .

E " H, 8° .

Plot the above, at 6 in. to 1 mile, and put in the contours at 20 ft. vertical interval.

XXXIV.

A stream rises at A midway between two hill-tops B and C, east and west of it, and each 100 ft. higher ; slopes from A to B and to C, 4° .

Two narrow spurs start from B and C, falling $1\frac{1}{2}^{\circ}$ for a distance of 1000 yds. to F and E, and bearing respectively from B and C 140° and 160° .

The sea is 300 yds. S. of E, the coast rising in a cliff 40 ft. high. The sea is 600 yds. E. of B.

The stream has an average fall of $\frac{1}{10}$ from A in a direction 157° for 500 yds., till it meets the northern slopes of the knoll D, where it divides, one half flowing S.E. into the sea a distance of about 1400 yds., falling in that length 50 ft.; the other half circling W. and S. round D till it loses itself in the marshy ground on the coast 200 yds. S. of D.

From the summit of D the bearing of C is 317° , of B 25° ; the angle of depression to the point where the stream divides, 5° .

Plot the above at a scale of $\frac{1}{100000}$, and contour it on the normal system.

XXXV.

A stream rises on the S. of and 20 ft. below the crest of a small plateau 250 ft. above the sea-level, and flows down a valley in a direction bearing 210°

for 730 yds. at an average fall of $\frac{1}{20}$. Here a second stream joins it from the N. and W., the ground at this point marshy, and the two united flow round the slopes of the hill A till they join the sea about 400 yds. S.E. of that hill.

From the point where the streams unite the bearings of two hills A and B are 126° and 278° , A being 50 ft. and B 30 ft. higher than the observer's position. The bearing from the same point to the col between A and B is 215° , distant 200 yds.; angle of elevation, $\frac{1}{2}^\circ$.

From this col the angles of elevation to A and B are 2° and 1° respectively.

The sea is 325 yds. S. of A, and 360 yds. S. of B.

At a point on the main stream 180 ft. above the sea an under-feature C bears 312° , distant 400 yds.; angle of elevation, $\frac{1}{2}^\circ$.

The col between B and C is 20 ft. below B, and the col connecting the under-feature C with the plateau is 20 ft. below C.

Plot the above at a scale of 6 in. to 1 mile, normal contours.

XXXVI.

B is an elevation at the head of a valley in which is a stream flowing easterly, and is 1000 yds. S. of a hill-top A.

C is an under-feature of A, the bearings from it to A and to B 73° and 139° .

The direction of the sea-coast is E. and W., and at a point S. of B is 220 yds. from that height.

A stream rises in the valley between A and B, its source 80 ft. above the sea, bearing from A 141° , from B 33° , and flows S.W. till it enters the sea S. of C.

From A and from B the angles of depression to the source of this stream are 2° and 1° .

From A the angle of depression to C is 1° .

40 ft. below A is a spur forming a plateau about 400 yds. across; in it is a lake, a stream leaving it on the E. and flowing down a valley in that direction; another stream rises under the col between A and C, and enters the sea at the same point as the main stream.

Plot the above at a scale of 4 in. to 1 mile, and fill in the contours at the normal intervals.

XXXVII.

From the mainland you wish to make a survey of an island to which you cannot gain access because of a channel, called the "half-mile water," on account of its width.

On an old chart, not drawn to scale, you find the

heights given. Thus the hill from which you intend to conduct the survey is marked 300 ft.; of the two peaks on the island, that on the N. is marked 90 ft., that on the S. 70 ft., the col connecting them 30 ft.

In appearance the island consists of these peaks, the slopes to the sea on the W. steep, those on the E. very gentle, stretching out into two low points, which enclose between them a bay.

The slope of the hill on which you stand is 10° , the base a cliff about 100 ft. high. From the summit the following observations are taken:—

Bearings to—

Northern shore of island,	64° .
Southern " "	118° .
N. peak "	75° .
S. peak "	109° .
Col "	91° .

Angles of depression to—

Eastern extremity of N. peak,	$21\frac{1}{2}^\circ$.
" " S. peak,	$2\frac{3}{4}^\circ$.

Plot the above at a scale of 4 in. to 1 mile, and fill in the contours according to the normal scale.

XXXVIII.

An irregular ridge, indented on the S. by the heads of two valleys, lies to the N. of and parallel to

the sea-coast, which here stretches E. and W; the extremities of the ridge marked by cairns C and D.

A and B, knolls below the ridge towards the coast, both the same height, angle of depression from B to the sea, $3\frac{1}{2}^{\circ}$.

Two streams rise under the ridge at points 180 yds. and 380 yds. from C, and flow southwards, uniting towards the E. of A, and then falling S. again till they join the sea.

General slope of the watersheds, 2° .

A line of telegraph, the poles 200 yds. apart, follows the coast; two of these are marked X and Y, the former W. of Y.

Bearings.

C to D, 95° .

A " C, 333° .

B " C, 350° .

B " D, 50° .

Y to A, 360° .

Y " B, 327° .

X " A, 45° .

X " B, 5° .

Angle of elevation from B to C, $\frac{1}{2}^{\circ}$.

The plan to be executed on the same scale as that of an old map of the same ground to which no scale was attached. On it, however, you find that the

distance between A and B is 1.6". On arriving on the ground you find it impossible to measure this distance as you intended, owing to the broken nature of the hills.

Plot the above on the required scale, and contour it on the normal system.

PART V.

S E C T I O N S.

XXXIX.

Draw a section of a hill from the following data:—

Scale for horizontal distances, $\frac{1}{10500}$.

" vertical " $\frac{1}{720}$.

Vertical interval, 12 ft.

A to B, rise of 4° in 200 yds.

B " C, rise of 6 ft. in 100 yds.

C " D, level for 80 yds.

D " E, rise of 38 ft. in 200 yds.

E " F, fall of 15 ft. down a slope of 3° .

F " G, rise of 18 ft. for 225 yds.

G " H, rise of 33 ft. for 150 yds.

H " I, fall down slope of 6° for 300 yds.

I " K, level for 150 yds.

K " L, rise of 25 ft., slope $\frac{1}{24}$.

L to M, fall of 30 ft. for 75 yds.

M " N, fall down slope of 2° for 220 yds.

XI.

You make the following notes of a detached hill of which you wish to take a careful section.

Commencing on the W., the angle of elevation from datum level is 2° . You pace up this slope till you come to where it changes to 4° , but have forgotten to count your paces, but a "reference point" on an adjacent hill gives your height at 78 ft. above datum. Before leaving the point where the slope changes you take the angle of elevation to the top of the hill and find it is 5° .

You now pace up the slope of 4° for 352 yds., when the slope again changes and continues at this fresh angle to the top of the hill, which you find by another "reference point" to be 200 ft. above datum.

The summit is a small plateau about 50 yds. across, and the slope on the E. to the datum is uniform at 6° .

Draw a section of the hill under the following conditions:—

Scale of horizontal distance, $\frac{1}{10380}$.

" vertical " $\frac{1}{980}$

Normal scale of contours.

XLI.

Draw a plan of the hill shown in section in the last example. On the N. the slope is uniform at 10° ; on the S. is a watercourse running in a direction due S. from a point 20 ft. below the summit; slope, 7° ; the slopes which enclose the valley in which it lies bearing about S.E. and S.W. at uniform slopes of 4° .

Scale the same as that of the section.

NOTES TO DIAGRAMS.

I.

SIMPLE exercise in finding the HE by the formula. The size of the lake is immaterial, as the slopes would be taken from its shore at points where the three bearings intersect it.

II.

Easy example of resection to fix the position of D.

III.

The height of the head of the stream being found by the fall given, that of A can be found, the distance and slope being also given. The position of B is found by calculating the HE between it and the head of the stream, and marking where this distance cuts the bearing taken to B from C.

IV.

An easy example of finding the heights, the slope and HE of one (A) being given. The cols should be taken at heights intermediate to contours. The fall of the stream and slope from D to the coast can be assumed.

V.

The scale not being normal, it must be drawn on the sketch.

VI.

An exercise in finding the height of hills by the formula, and of plotting in contours where several valleys unite.

VII.

The point which the "section line" followed arrives at N of the knoll is 15 ft. above the sea. Find the HE of B from this level (slope and VI given), adjust your compasses to this distance, and when they cut the bearing of B from the knoll, being placed at right angles to the "section line," the position of B is fixed. The line thus fixing it being produced to the right fixes the position of A, when its height can be found by the formula.

VIII.

An example of "form lines" marking the change of slope on a "section line"—that on A occurring at $2\frac{1}{2}$ contours, on B at $2\frac{1}{3}$ contours, and on C at $3\frac{1}{2}$ contours from the highest contour.

IX.

An example of filling-in a small space with several conventional signs—*e.g.*, a plateau, a valley, a col, an under-feature, and a spur. To produce a satisfactory sketch the head of the valley must make a considerable indentation in the plateau at the named point.

X.

Easy exercise in plotting, and calculating the VI by the formula. None of the summits are on contours, so they may be indicated by "form lines."

XI.

An easy example of traversing in a hilly country; the traverse should close on D.

XII.

The entries mark the contours on a "section line" up to the top of the hill at II, a "form line" marking one station. If the work is done carefully the final station will close on I.

XIII.

The scale is found by comparing the size of the plan with the area of the ground to be sketched. $\frac{3}{4}$ of a mile is to be represented by 3 in.—*e.g.*, 4 in. to the mile.

The plateau not falling on a contour must be indicated by a "form line."

The lowest part of the ground shown will be 90 ft. above datum level.

XIV.

The positions of B and D are found by finding the HE from the points on the traverse line from which the angles of elevation are taken, setting the compasses to this distance and marking where they cut the bearings

from I. None of the points marked on the traverse line are on contours, so care must be taken to find the exact height of the spot whence the heights of B and D are taken. The col between C and D is taken in the sketch at 45 ft.

XV.

An example of contouring a road, the sketched noting a station at each contour. The slopes are 1° , $1\frac{1}{2}^\circ$, 1° , 2° , and $2\frac{1}{2}^\circ$, 2° , 5° , 2° . The general gradient is found by calculating the height over the distance.

XVI.

The initial contour is taken 25 ft. below the highest point so as to show more exactly the general shape of the hill. It is traversed with great care and "section lines" taken down the principal features.

XVII.

The scale not being normal, a scale of slopes must be added to the plan.

XVIII.

An example of a road carried up a slope at a gradient less steep than the slope. The height of I station must be assumed at above 0, otherwise the river when crossed by the road will be a *minus* quantity. The shape and size of the ridge are only roughly shown by the bearings, and the contours W. of it lend themselves to several modes of rendering.

XIX.

The zigzag lines represent the windings of the road, the arrow-heads are "section lines" taken down the hill at right angles to the traverse line. First mark off the contours on the traverse line, the last will be 60 ft. The road in one instance only cuts one of these, so in calculating the slopes care must be taken to allow for the fraction of a contour from whence the "section line" starts.

XX.

The irregular line represents the initial contour, its height above the sea found by the distance and slope given from IV—viz., 120 ft. The height of the knoll is found in the same manner.

XXI.

The crest line being drawn and its height determined by the rise from I, which can be assumed at any height above datum level, the lowest point of the stream is found from IV.

XXII.

An example of the use of "reference points." At III three points are found to be on the same level as the observer. The height of III is not known, but that of the N. bridge can be found by the fall of the stream to be 120 ft., and as that is one of the points on the observer's level, it follows that III is at 120 ft.; also the col between A and B, and station I.

XXIII.

An example of "form lines" used to denote a change of slope. The height of A is found by working up from the sea at F; the intermediate heights at E and D, also that of A, being found by the formula. The heights of G and H should be found in the same way.

XXIV.

Easy example of "form lines" marking a change of slope. The intermediate points B, D, E, and F should have their respective heights calculated by the formula; the distance to the sea from B, E, and F can be found in the same manner. As the scale is not normal it must be added to the sketch.

XXV.

An example of "form lines" showing features intermediate between contours which otherwise would not appear. The height of A is obtained from section line A 5.

XXVI.

An exercise in "form lines" to indicate a change of slope. The height of C is found by the slopes and distances given by the "section line," then the heights of A and B can be found. Care should be taken to show the indentations in the coast-line.

XXVII.

An example of intersection and resection. The height of A being found from the rock in the sea which is assumed to be 0 ft., the other heights follow.

XXVIII.

The scale is found by making a length of $2\frac{1}{2}$ in. on the plan, equal to 1100 yds. on the ground.

The lake must be assumed at a sufficient height above datum level to allow for the fall of the stream on the S.E.

The size of the plan will be nearly 4 in. square.

XXIX.

An example of intersection and resection, the heights of the hills found by the formula. The lake is taken as datum.

XXX.

An example of "form lines" marking a change of slope, and of slightly more difficult contouring. The height of A is found by the "section line" to the sea. The cols should be placed so as to make the contours of the main valley fit in neatly.

XXXI.

An example of the use of conventional signs, and of calculating the value of the points of the compass in degrees. N.N.W. is the second point from N, each

point being worth $111\frac{1}{4}^{\circ}$; the bearing of the stream will be 337° from D. The fall of the streams must be calculated from D.

XXXII.

A more advanced example of filling in contours where several valleys meet. The larger the lake the more distant will be the point H. The positions of A and B are found by calculating the HE from the lake-shore and marking this distance along the bearings from it.

XXXIII.

The bearing 282° taken through M gives the direction of D; its distance is 700 yds. E. of M. The knoll K should be left till the surrounding contours fix its shape.

XXXIV.

The distance of B and C from A is found by the HE, slope and VI being given; the height of A by calculating the fall of the stream to the sea in the S.E. corner. The knoll D is found by resection, and requires care in filling in the contours.

XXXV.

The point where the streams unite must be carefully found and its height noted. The main stream rises two half contours below the plateau. An example of working with fractions of a degree. A good deal of the position of the contours is left to the draughtsman.

XXXVI.

The 90-foot contour forms the edge of the plateau, the position of the lake on it has always seemed to be the difficulty of the example.

XXXVII.

An example of surveying an inaccessible object. The western slopes of the island can be assumed, in the sketch 12° is taken. The eastern extremities of the island are found by calculating the HE from the top of the hill on the mainland.

XXXVIII.

To find the scale, make an independent triangulation of A and B from the base XY at any convenient scale ; this gives the distance between them in yards, when the RF can be found and the sketch made on that scale, beginning as before from the base XY. The heights of A and B are found by the slope from B to the sea.

XXXIX.

There is no difficulty in this problem, only care must be taken to mark the exact spot between contours where the vertical distances cut the uprights. The vertical scale is the 60 on the Marquise Scale. If properly worked out the slope ending at N should be on the same level as A. The highest point is 122 ft. above datum level.

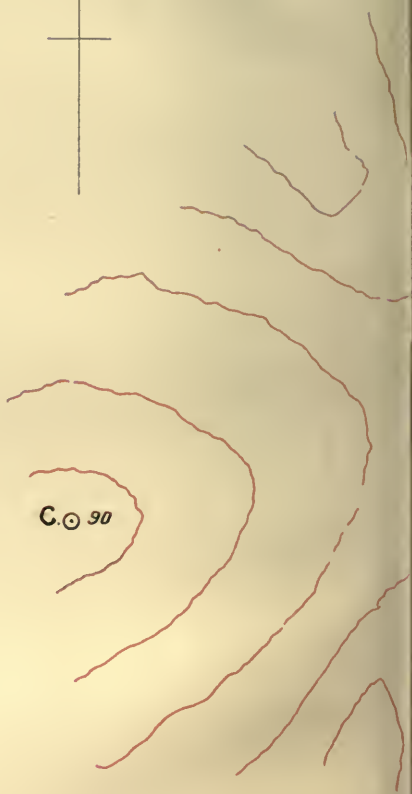
XL.

The horizontal distance for the initial slope is found by the height, 78 ft., and the slope 2° . From this point the distance to the top of the hill is found in the same way. The intermediate point, to which the slope is 4° , is found by calculating its height, the horizontal distance and slope being given, and adding the result to the height of top of the first slope, 78 ft. The scale for vertical heights will be found to be $12\frac{1}{2}$ on the 50 Marquise Scale.

XLI.

A datum line must be drawn of the same length as that of the section, the points on it which the contours cut being dotted off on a slip of paper and transferred to this datum line for the plan, care being taken to number them according to height. The slopes N. and S. of the summit can then be dotted in, and the contours traced round the central hill-top. It is merely to take a section of a plan reversed.

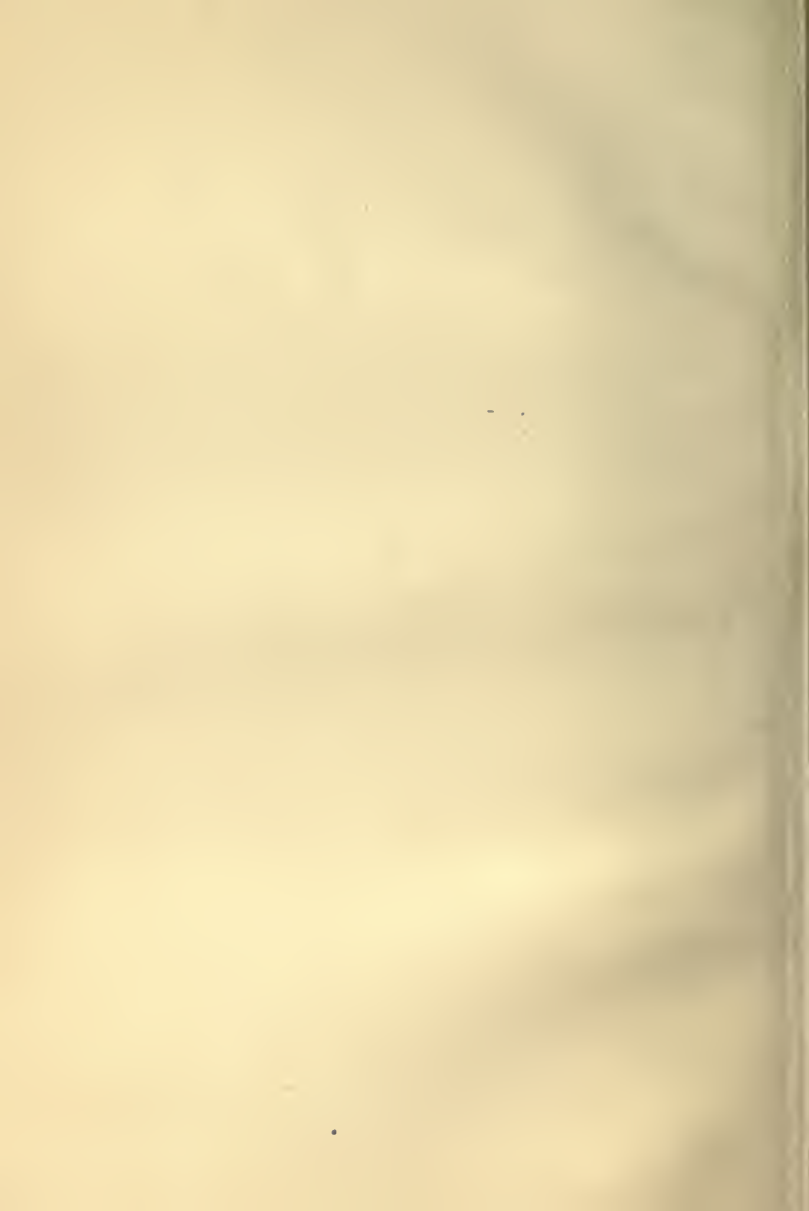




C. 90

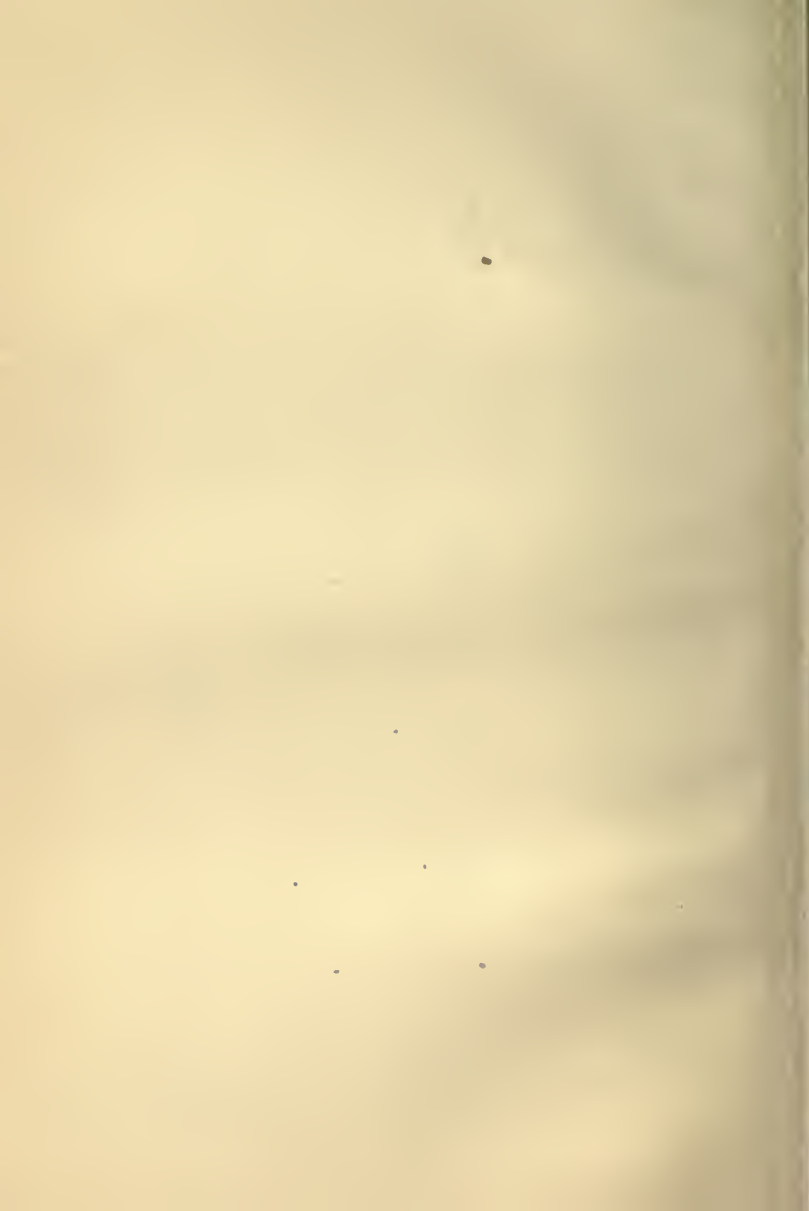


Scale, $\overline{10360}$. VI. 20 feet.





Scale. $\frac{1}{10560}$. VI. 20 feet.





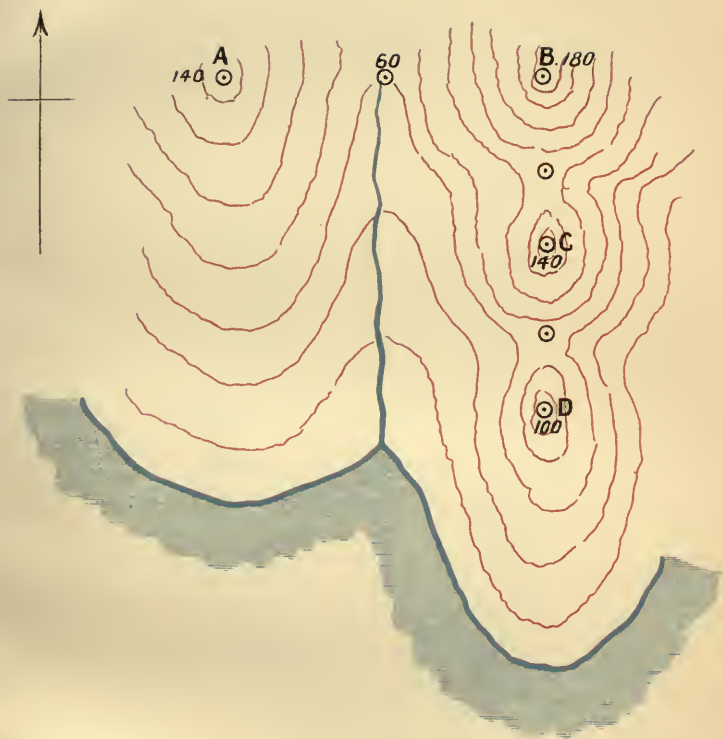
A.240 ☉



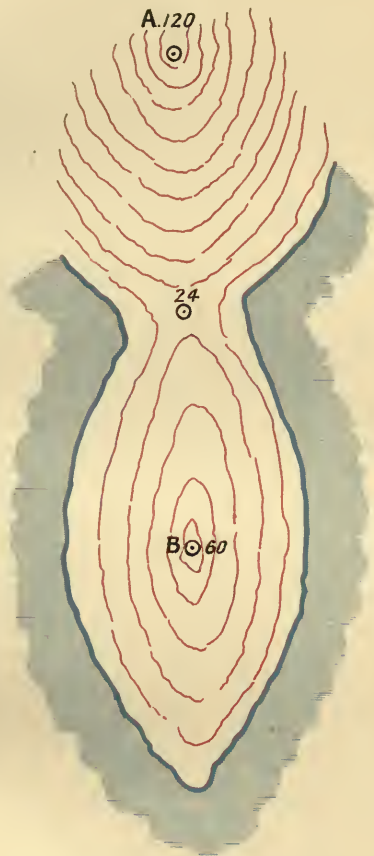


Scale. 10360. VI. 20 feet.



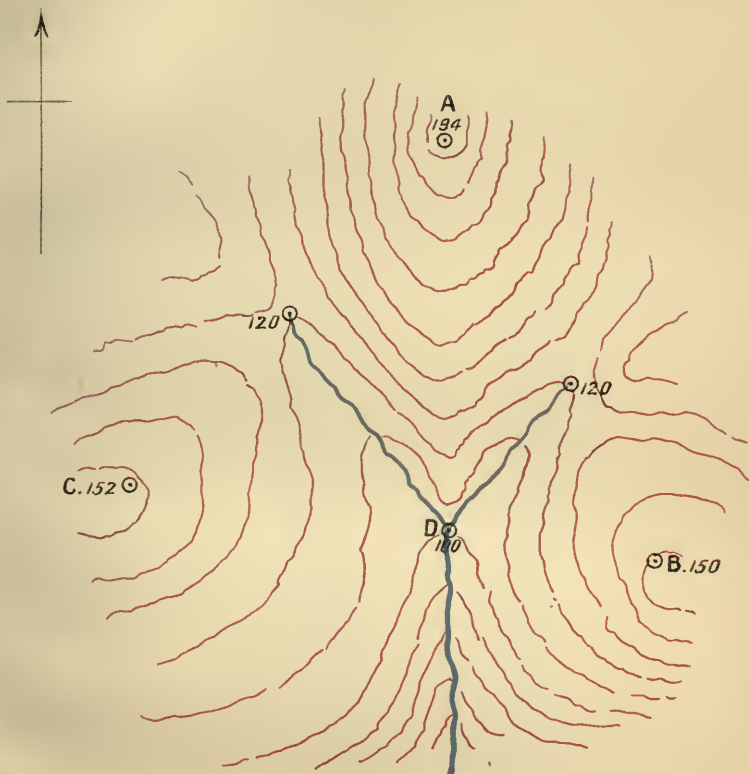


Scale. $\frac{1}{10560}$. VI. 20 feet.

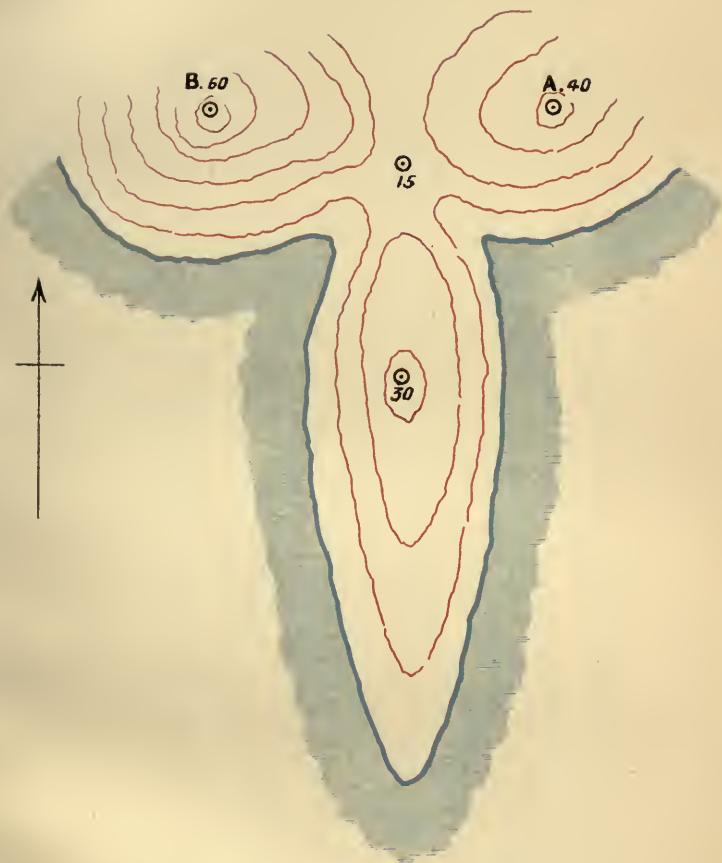


Scale. $\frac{1}{3280}$ VI. 12 feet.

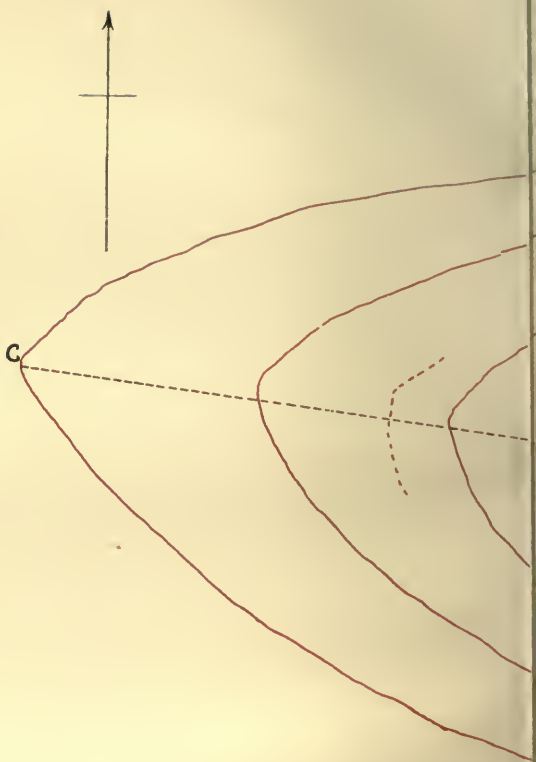
Scale of Horizontal Equivalents.



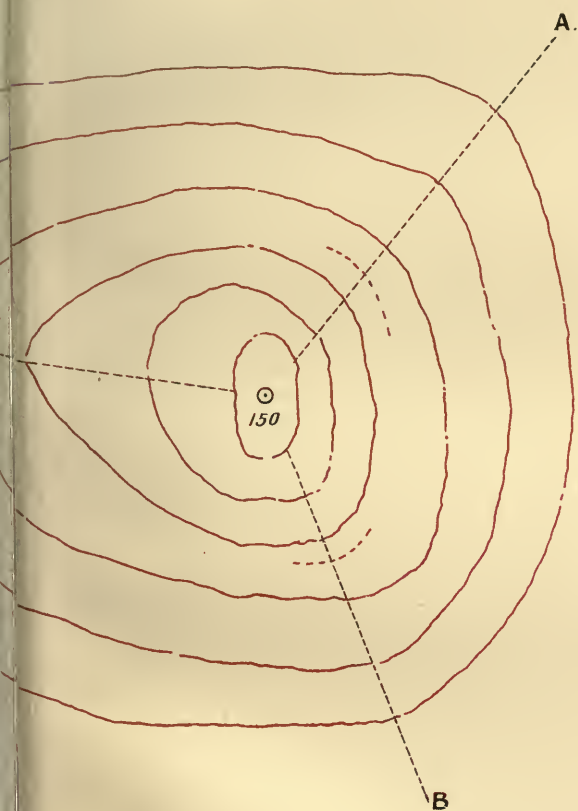
Scale. $\frac{1}{3200}$. VI. 10 feet.



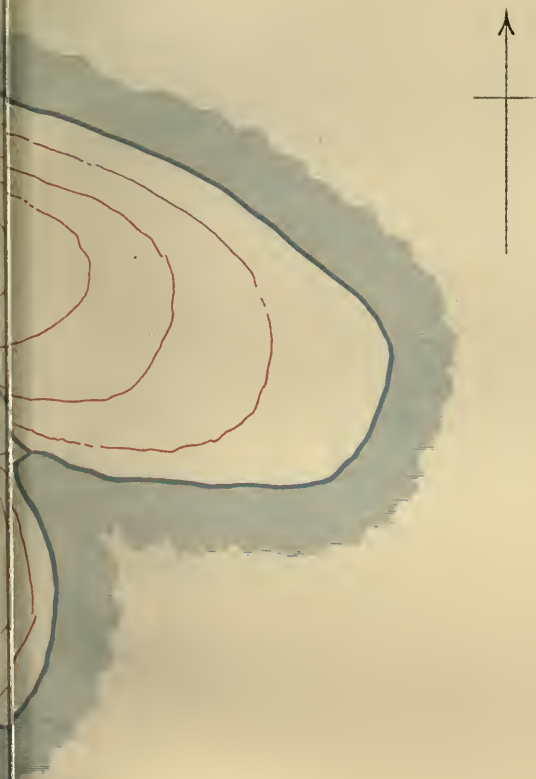
Scale $\frac{1}{3280}$. VI. 10 feet.



Scale. $\frac{1}{15840}$. VI. 30 feet

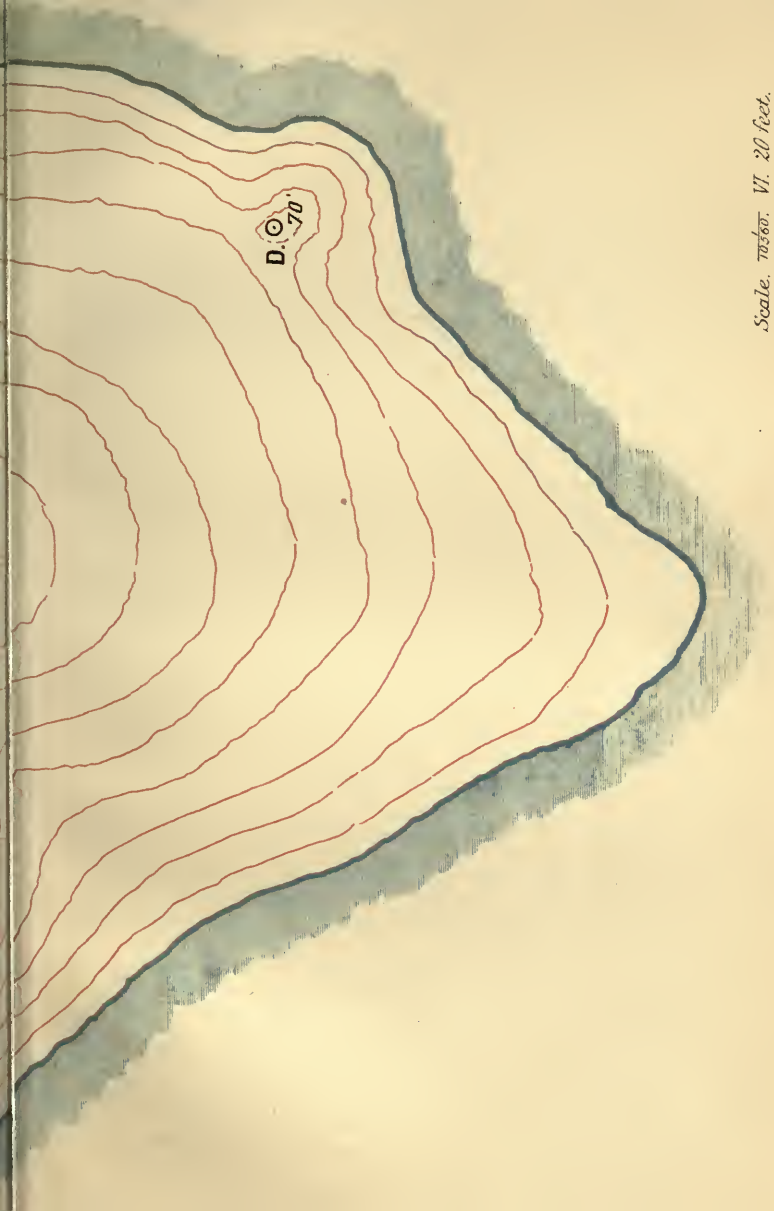






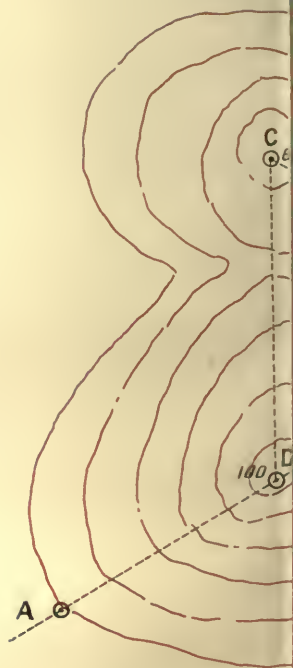
Scale $\frac{1}{10560}$. VI. 20 feet.





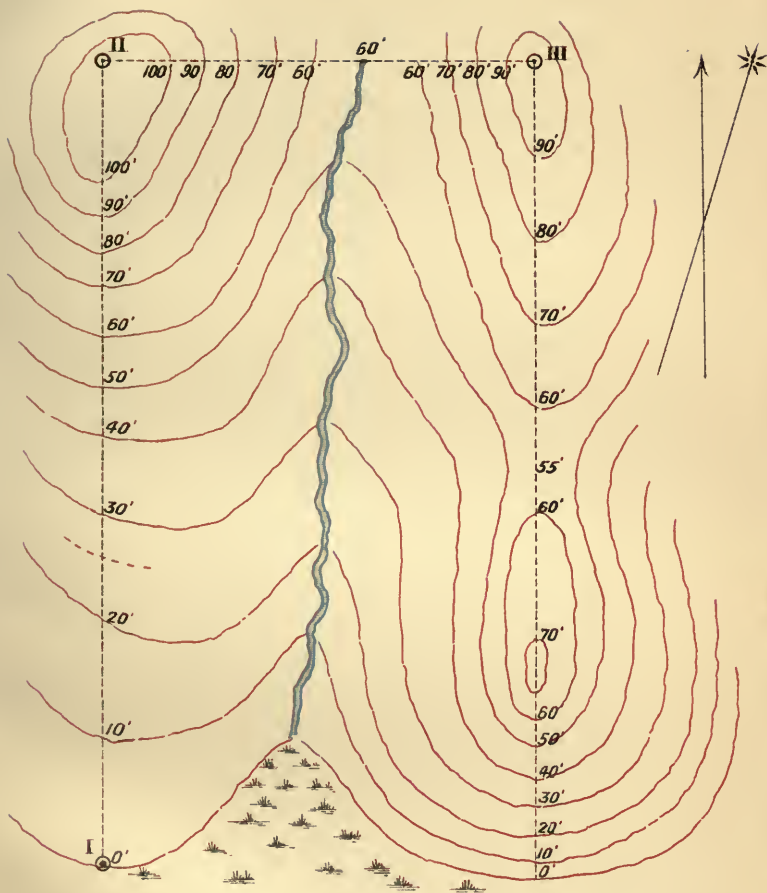
Scale. 70360. VI. 20 feet.



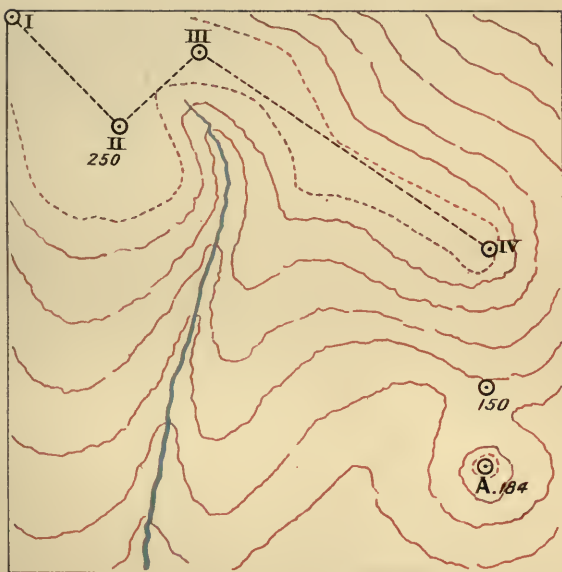




Scale. $\frac{1}{10560}$. VI. 20 feet.



*Scale. 12" to 1 Mile.
Contours Normal.*

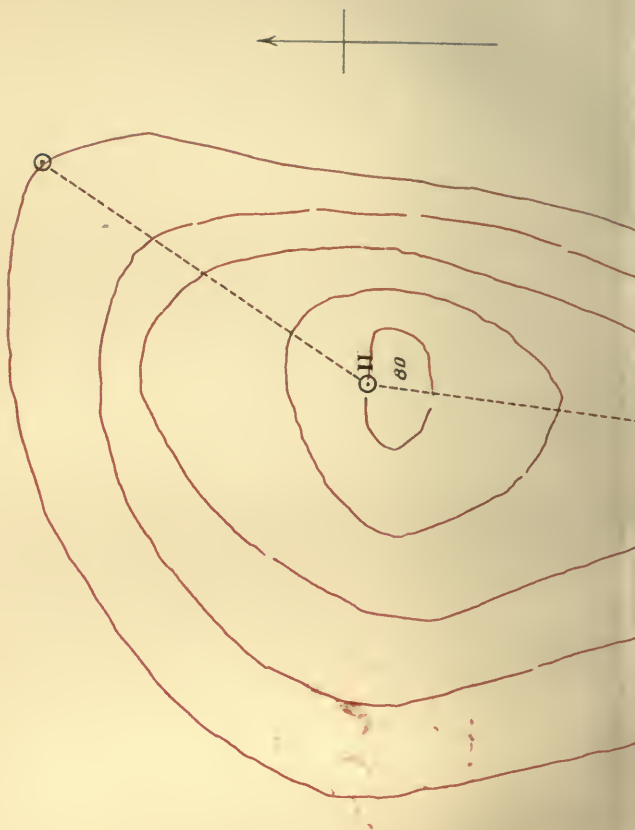


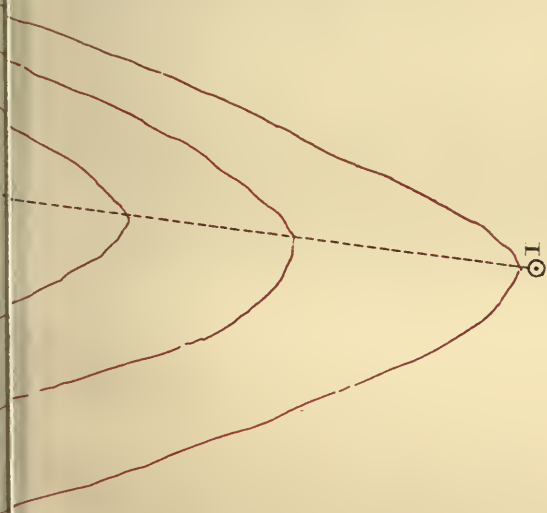
Scale. $\frac{1}{15840}$. VI. 30 feet.



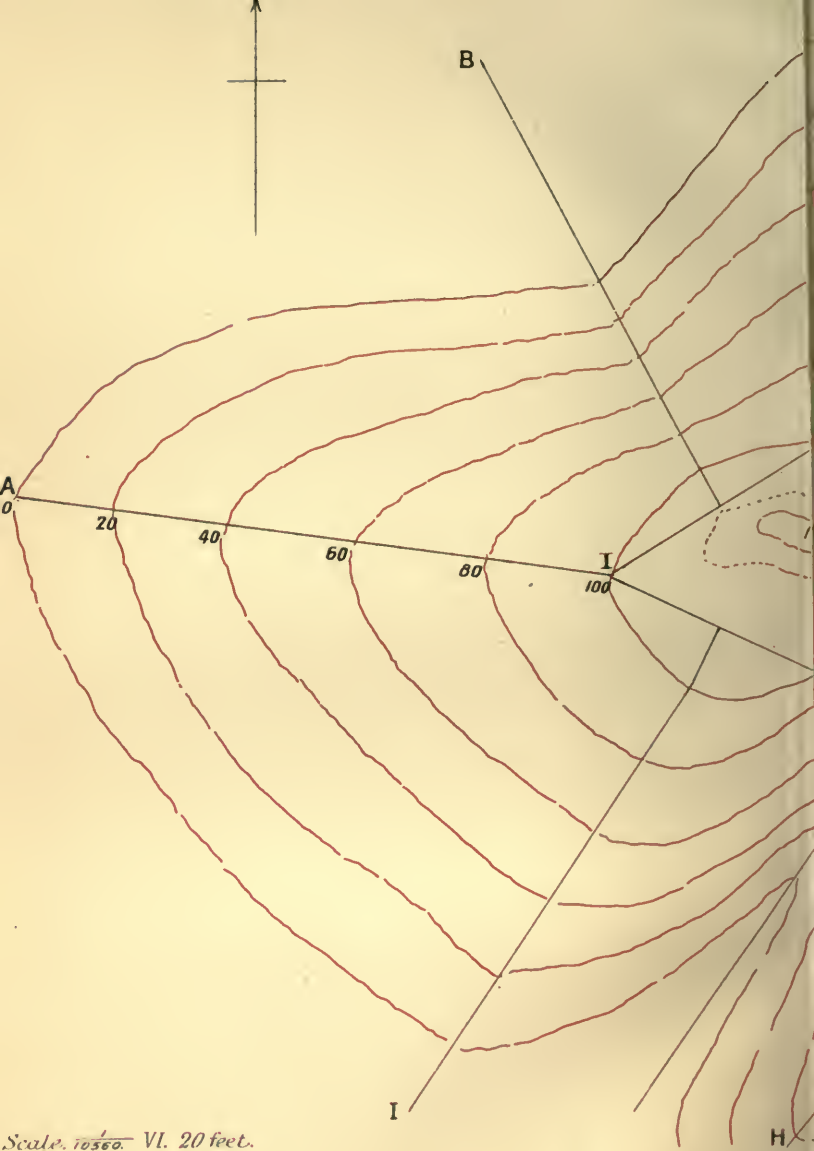


Scale, 70300. VI. 20 feet.



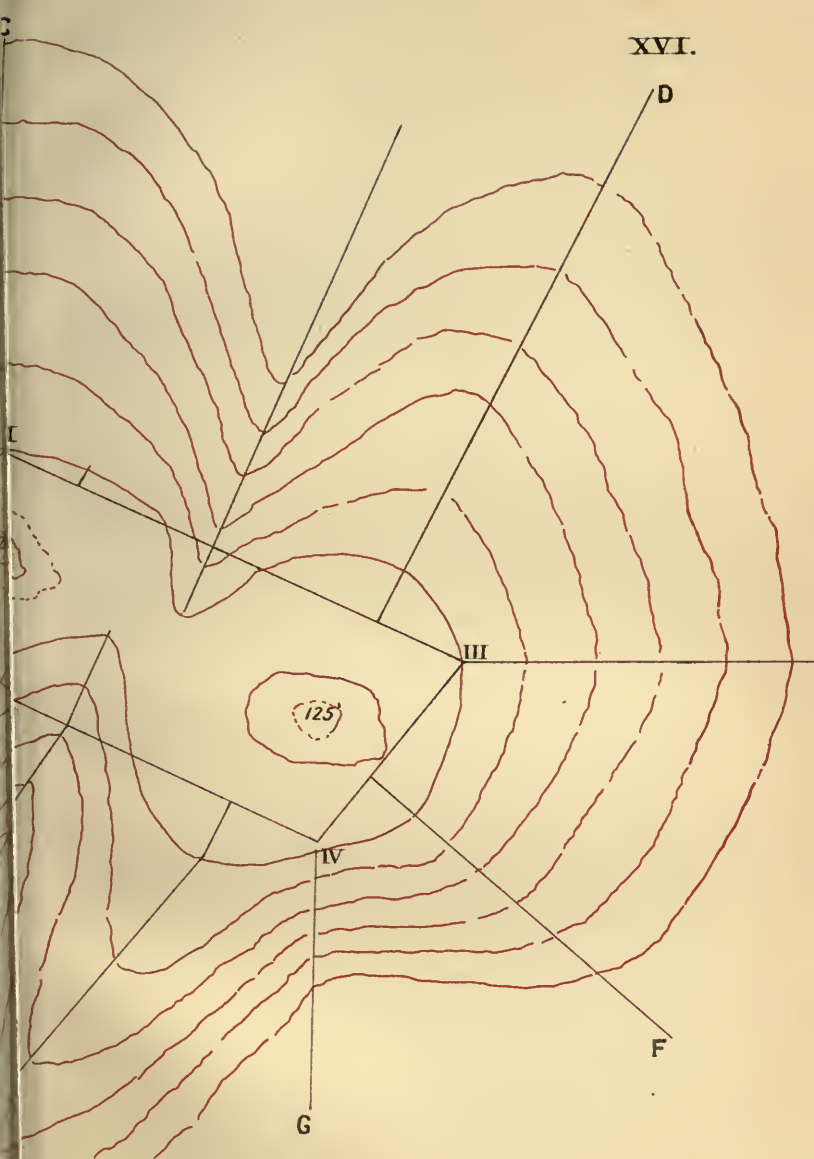


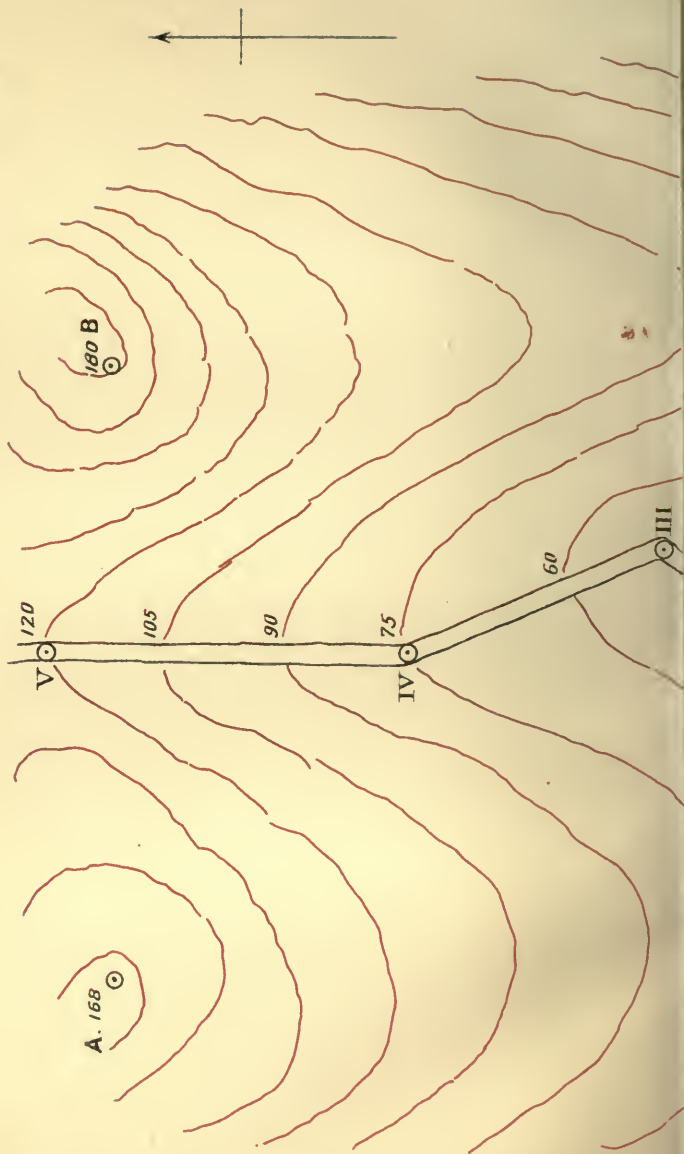
Scale, 10560. VI. 20 feet.

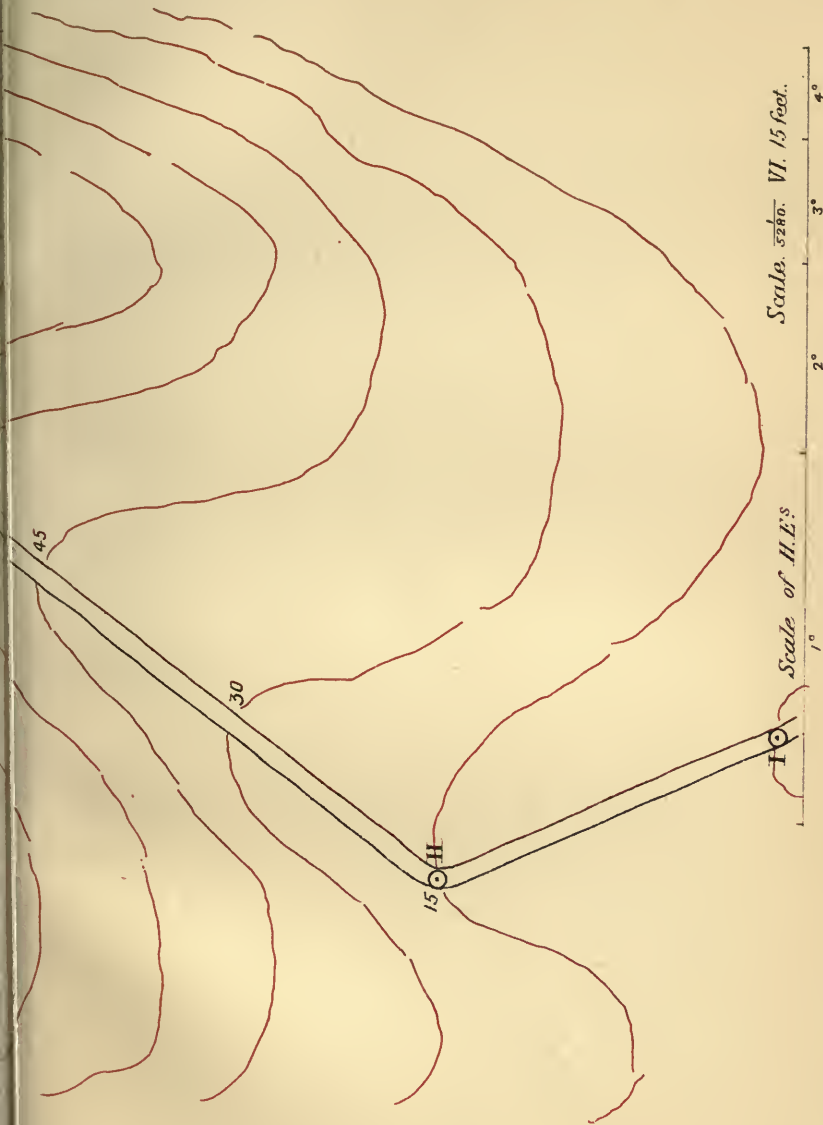


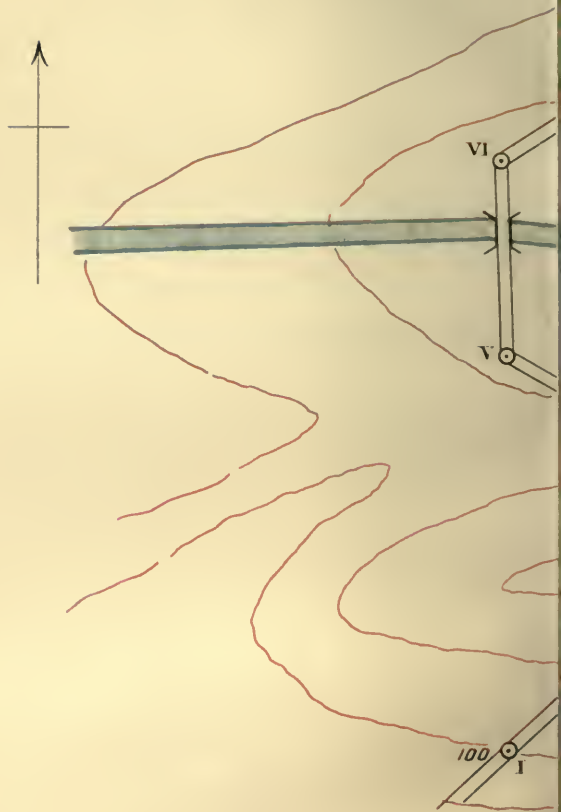
Scale. $\frac{1}{10560}$ VI. 20 feet.

H

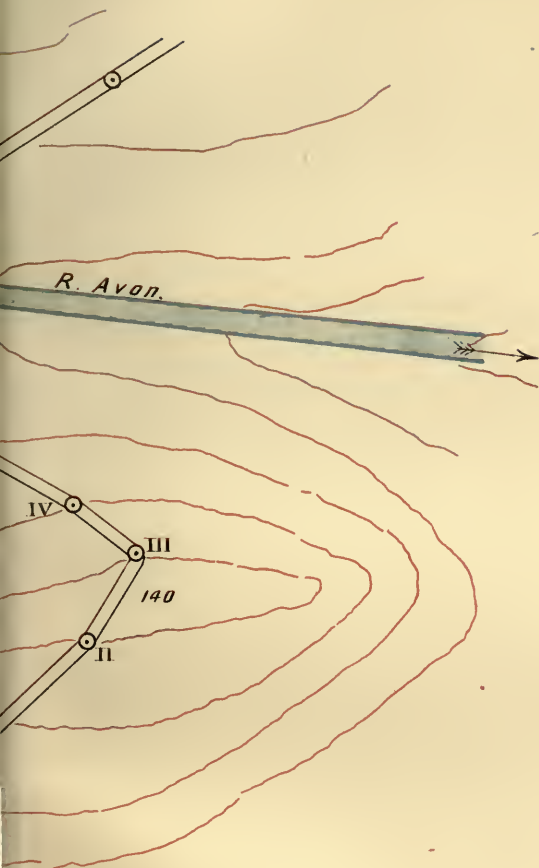


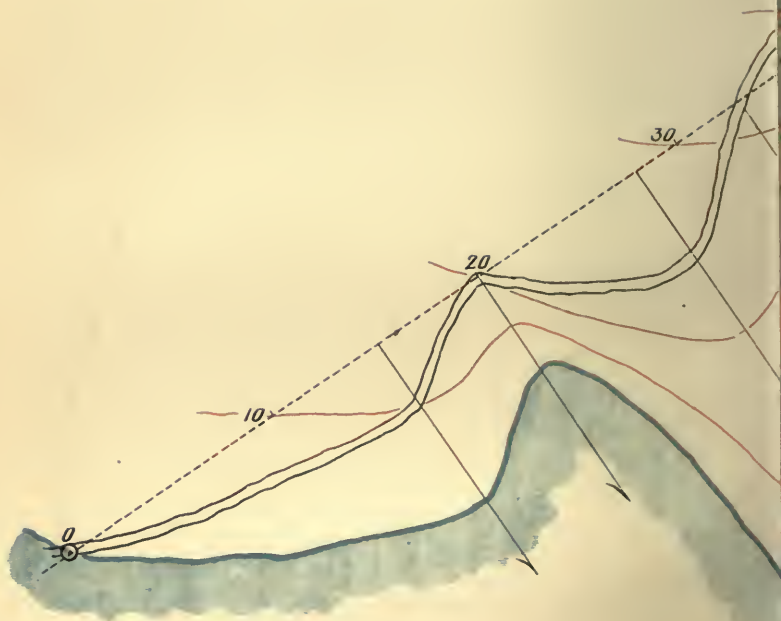




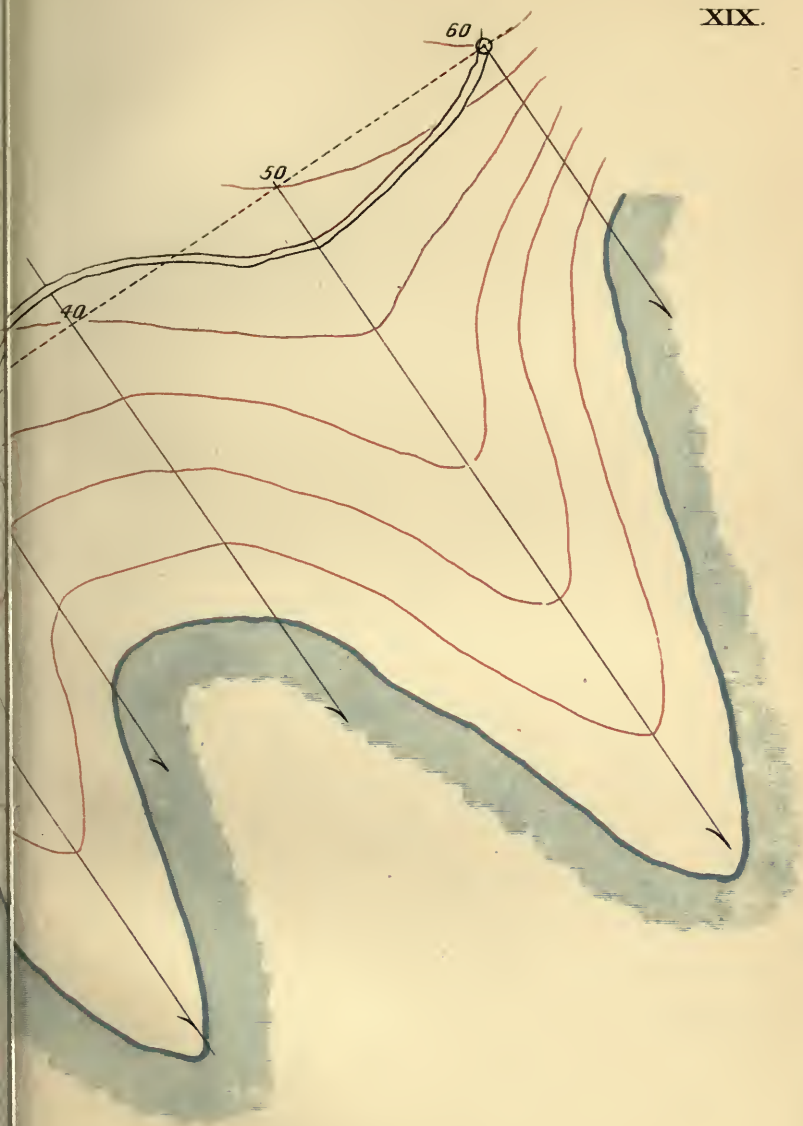


Scale. $10\frac{1}{320}$. VI. 20 feet.





Scale $3\frac{1}{2}$ in. VI 10 feet.



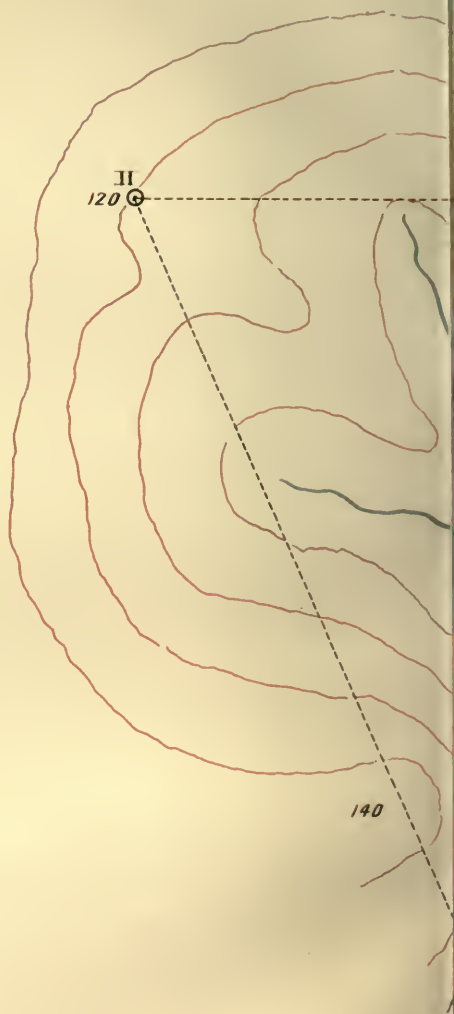


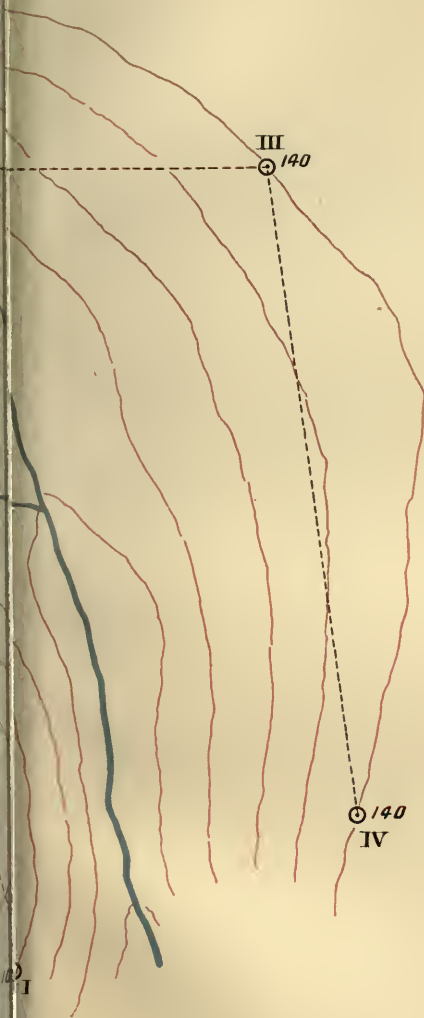
1/20



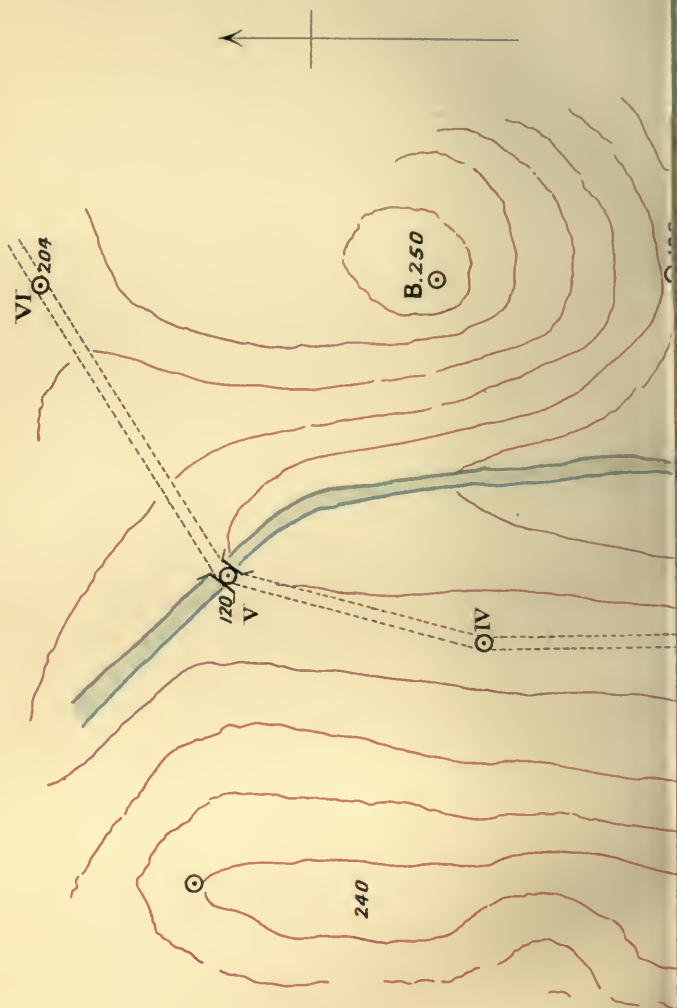


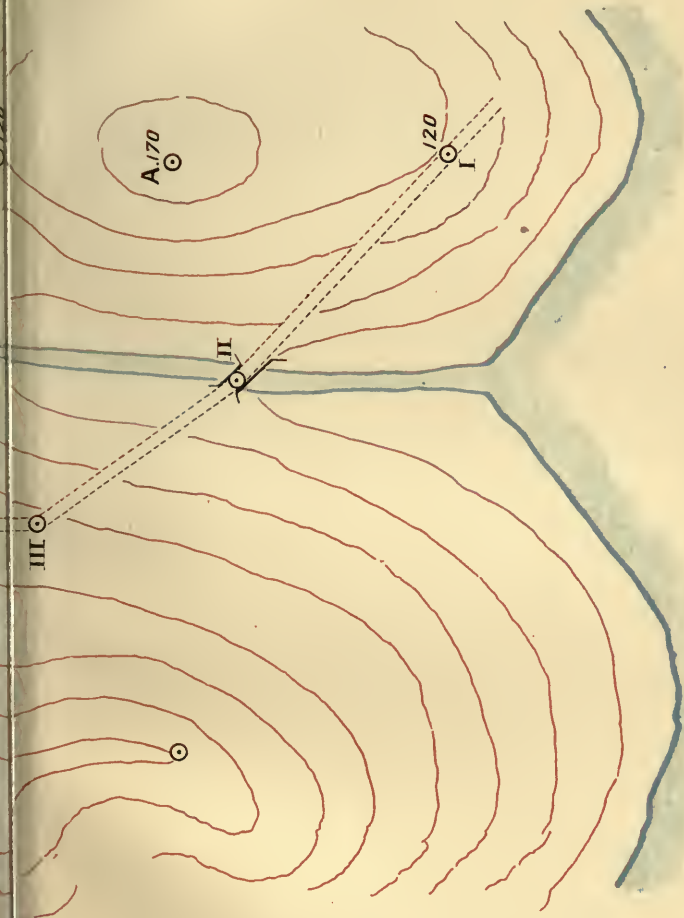
Scale. $\frac{1}{3840}$. VI. 30 feet.



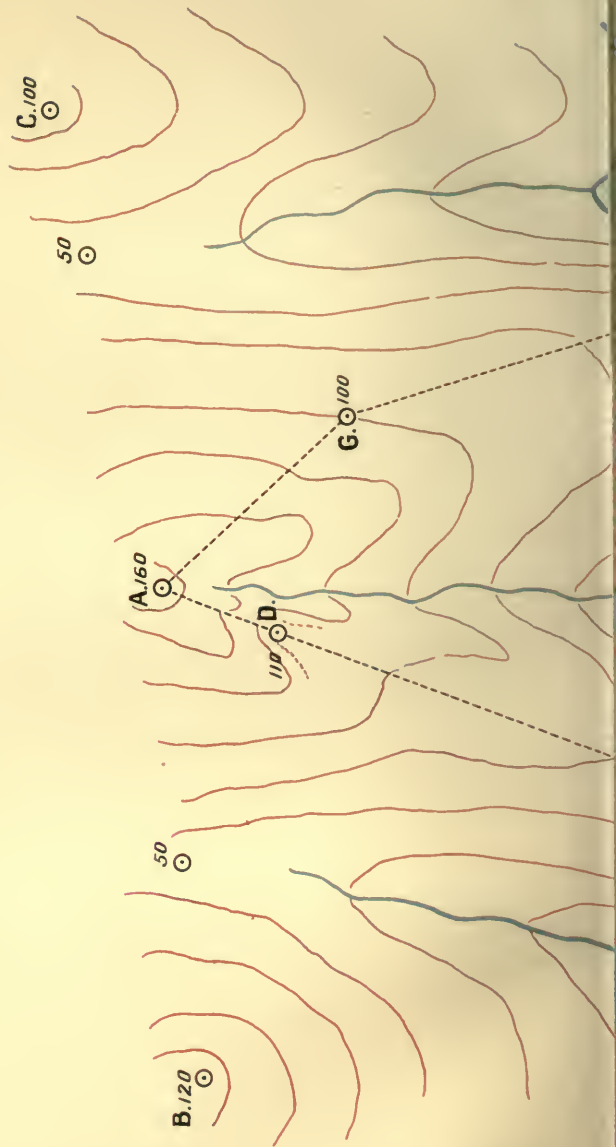


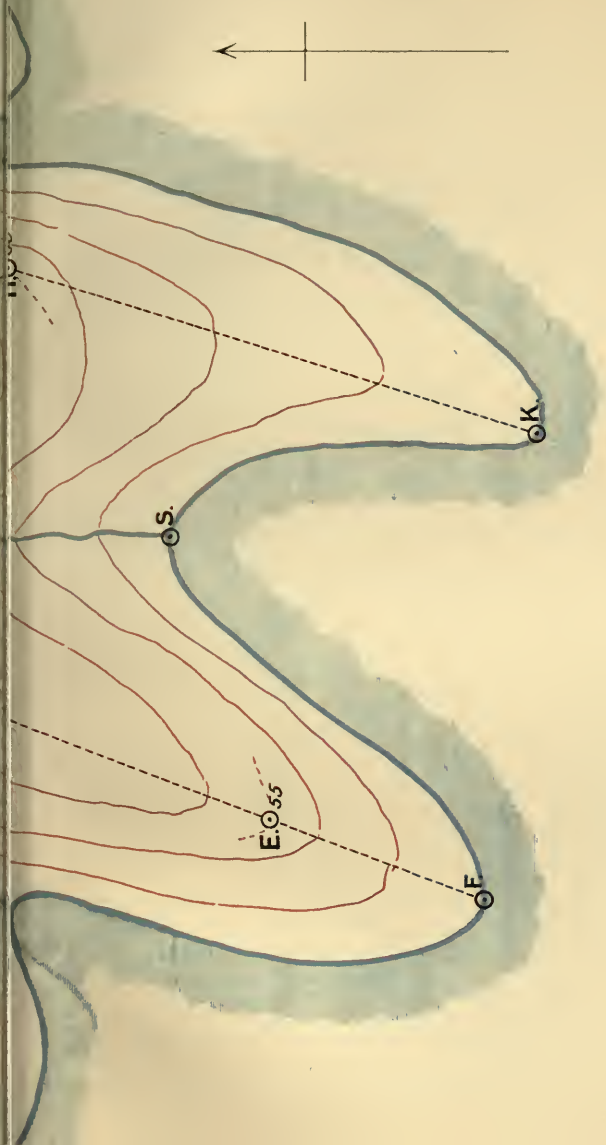
Scale. $\frac{1}{10560}$. VI. 20 feet.





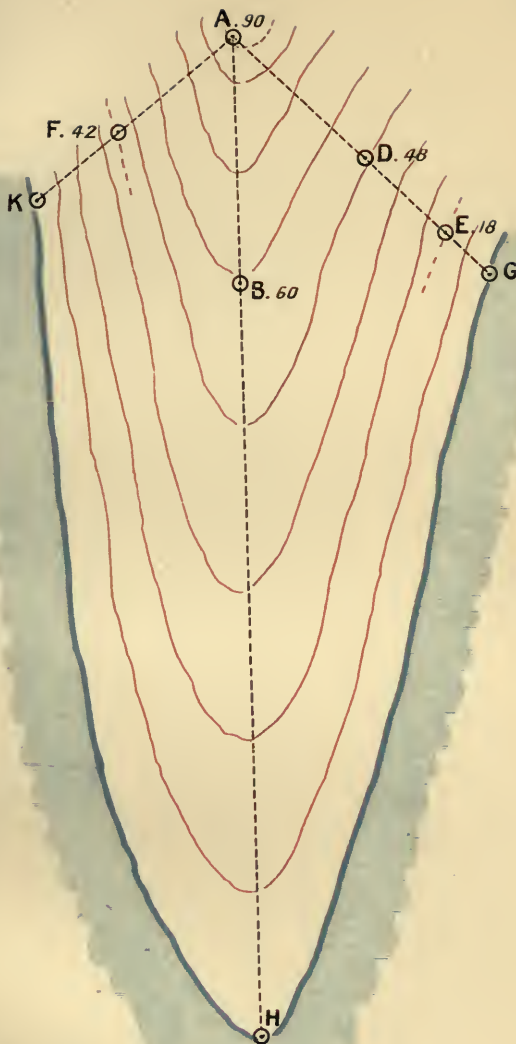
Scale 13640. VI. 30 feet.





Scale 10000 VI. 20 feet.

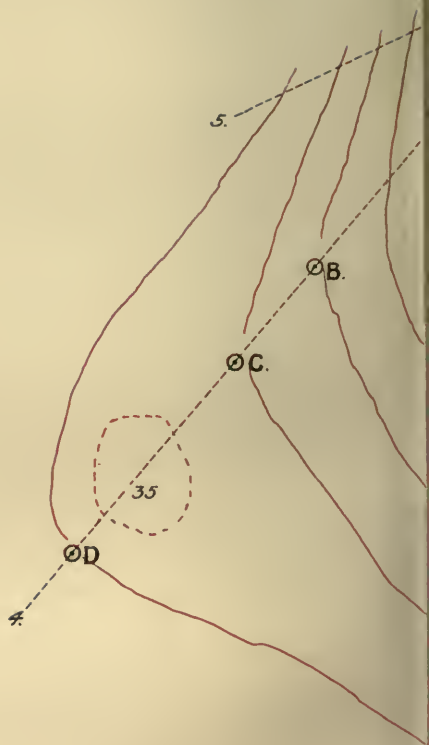




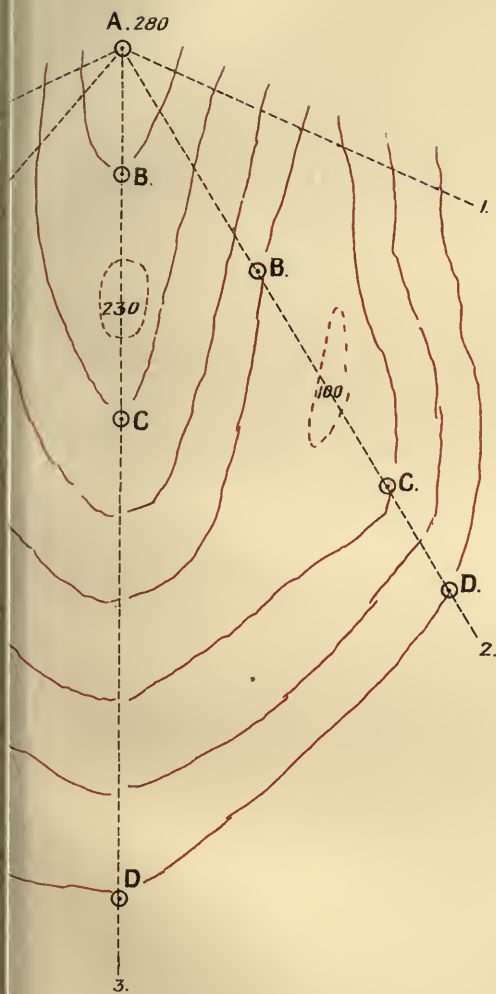
Scale. $\frac{1}{3280}$ VI. 12 feet.

2° 3° 4° 6° 7° 8° 10°

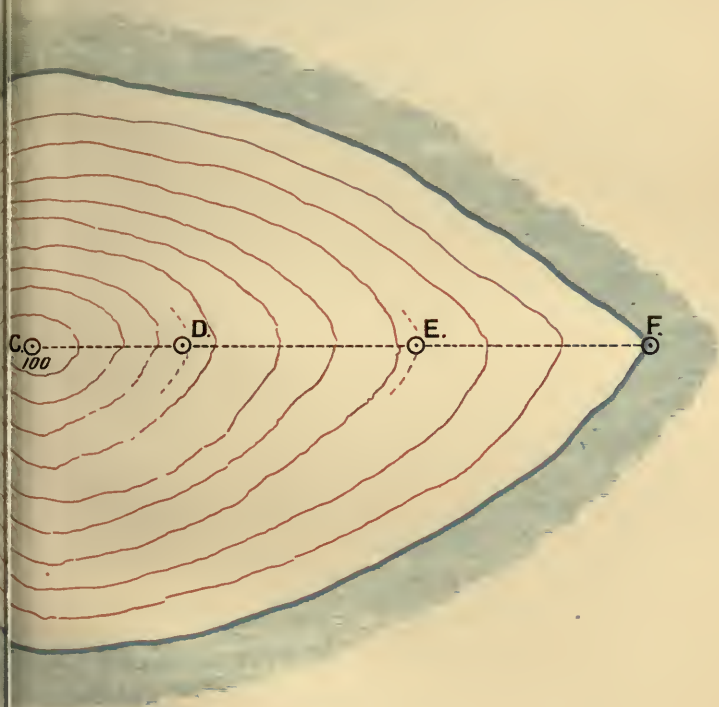
Scale of H.E.s



Scale. 3 inches to 1 mile. VI. 40 feet.







Scale $\frac{1}{3280}$ VI. 10 feet.

C.230

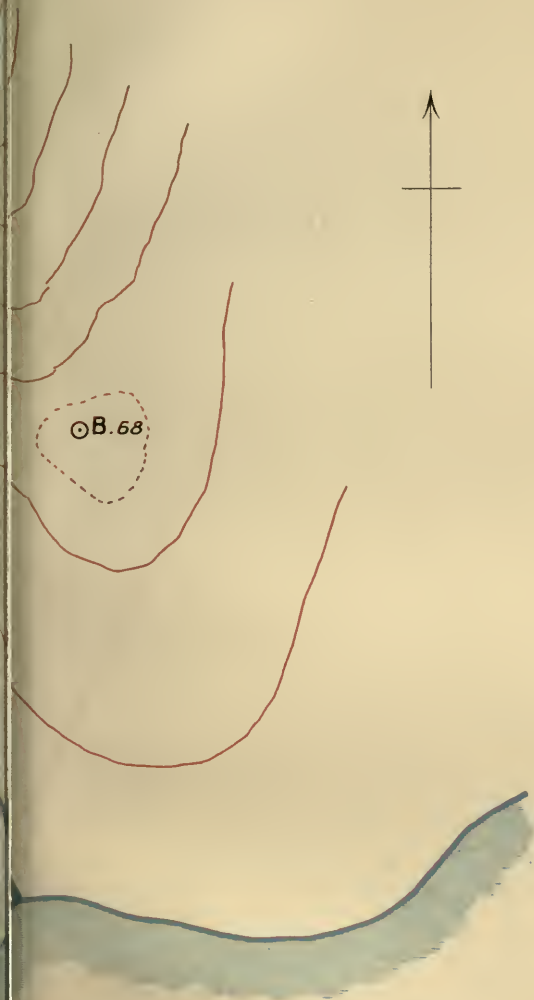


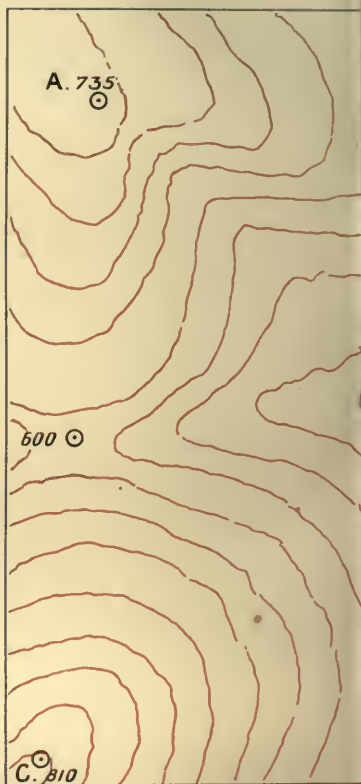
60

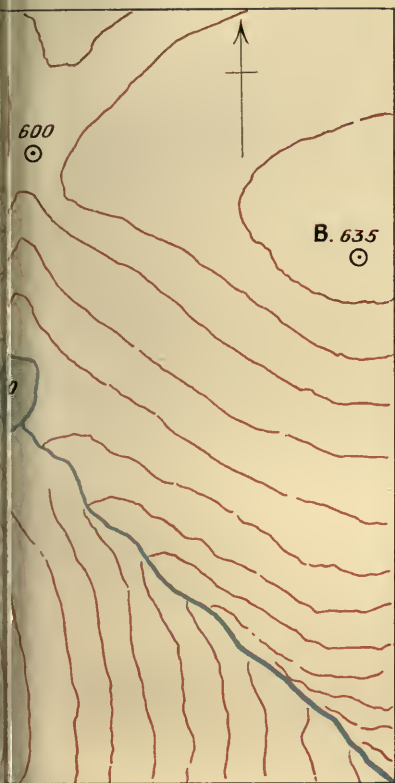


A.138

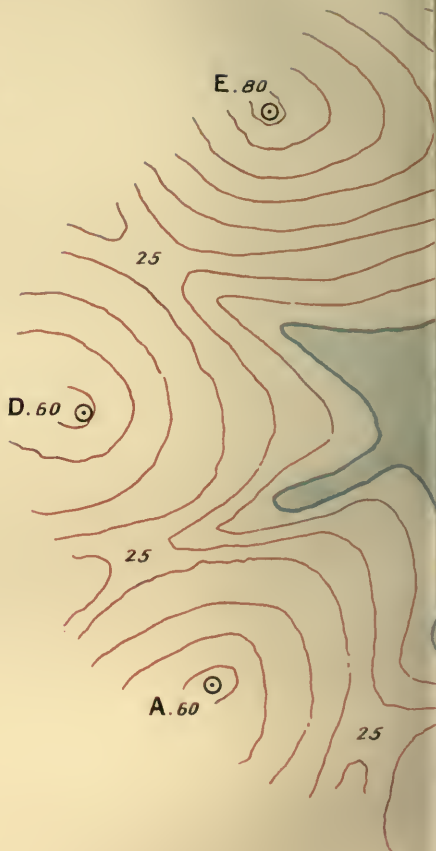


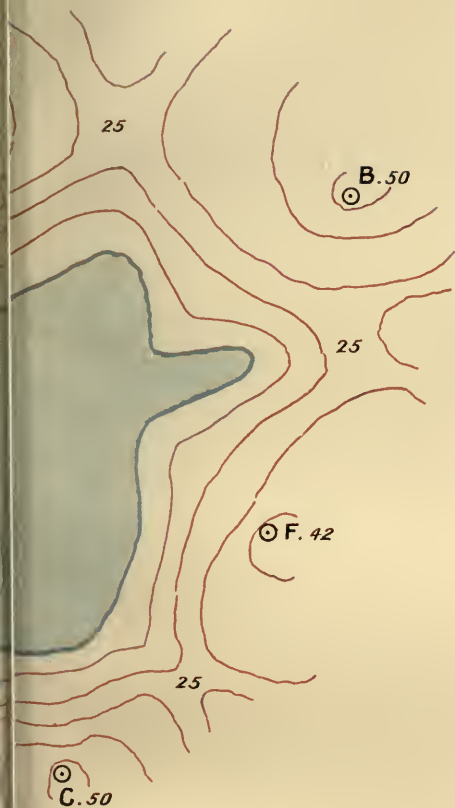




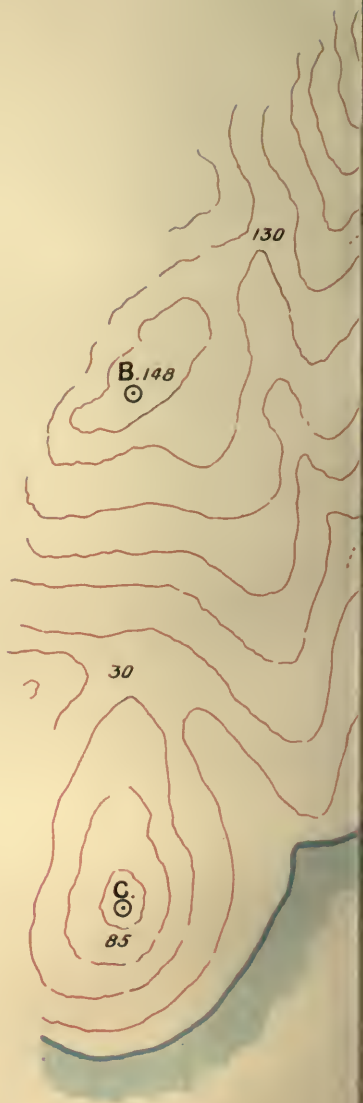


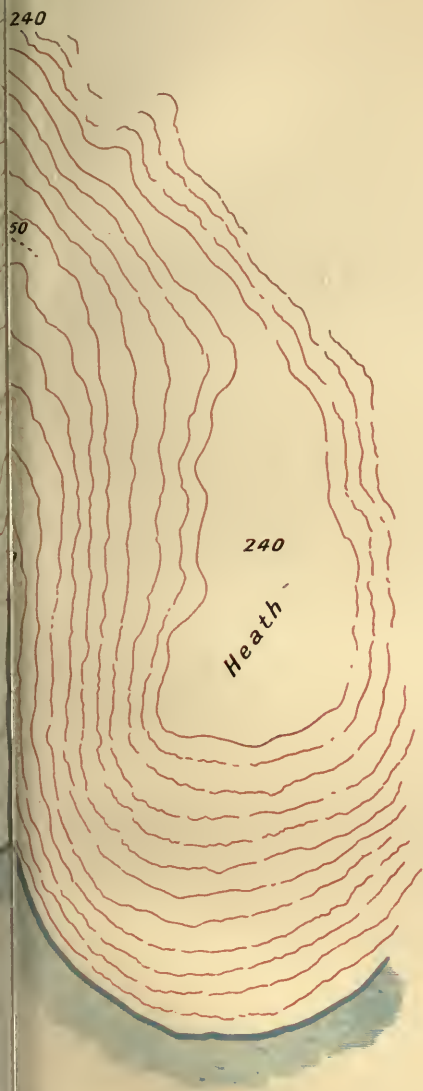
Scale $\frac{1}{13840}$. VI. 30 feet.



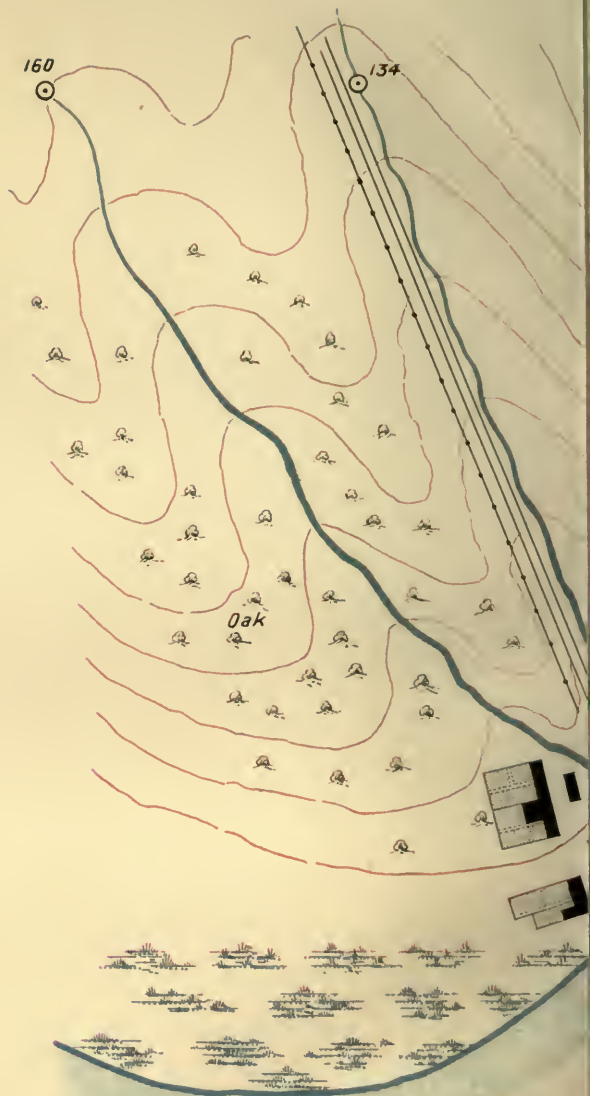


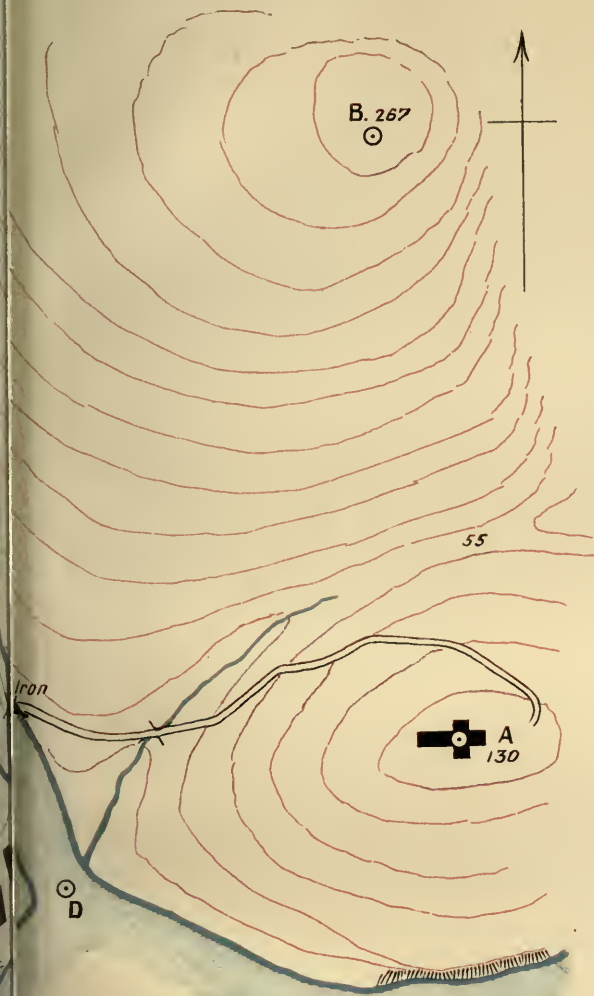
Scale $\frac{1}{3840}$. VI. 10 feet.











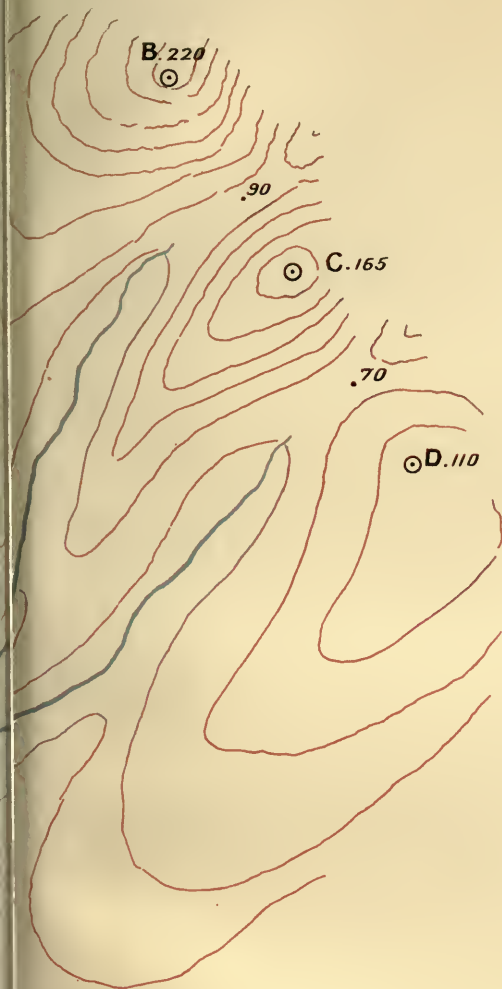
A. 220

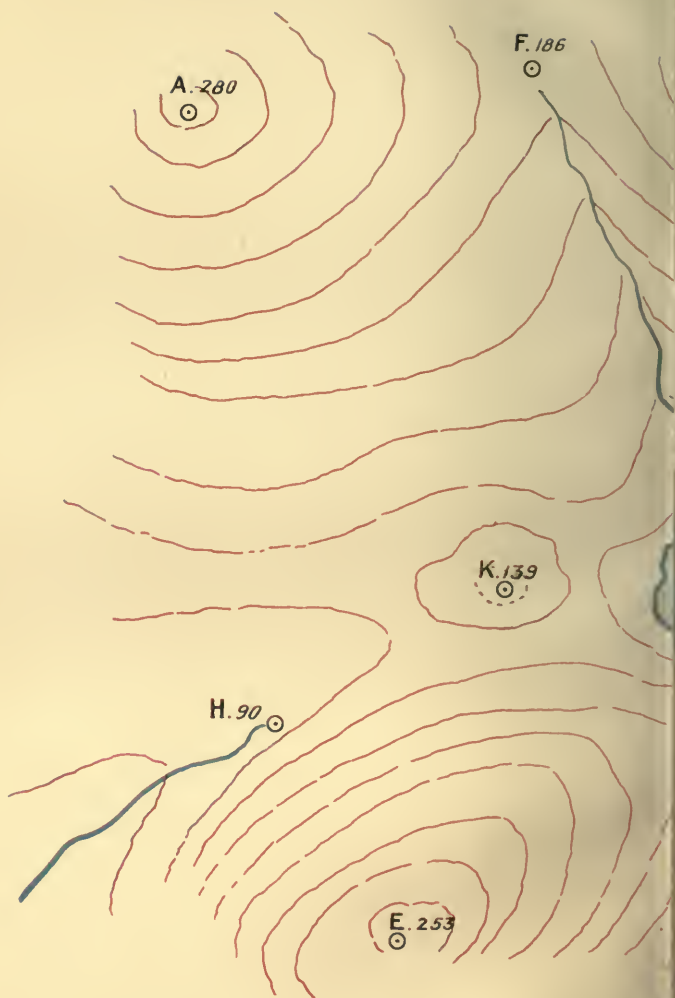


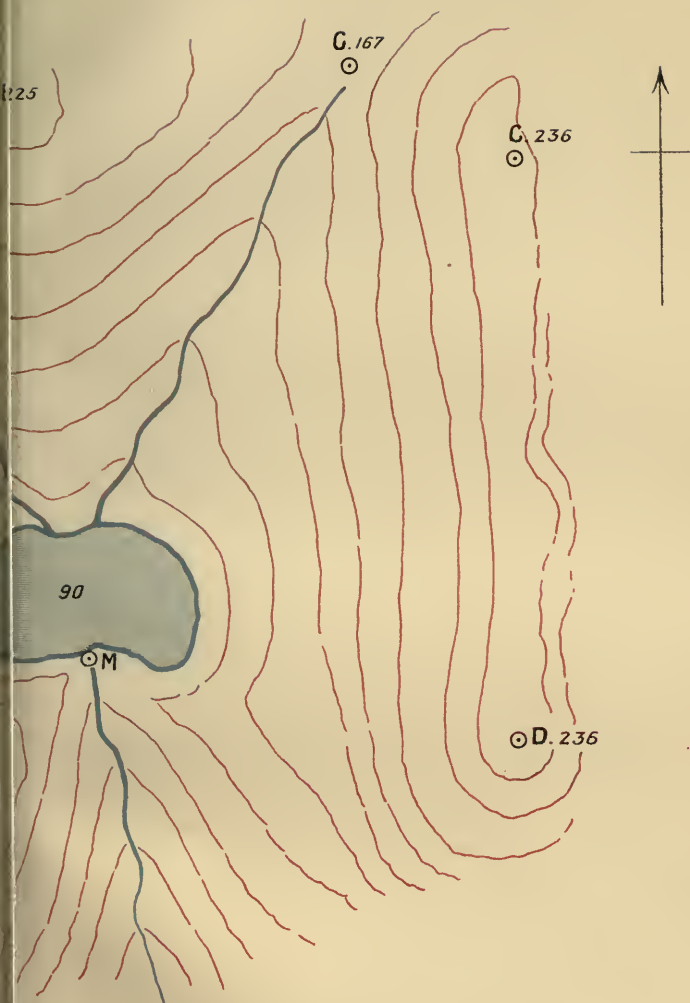
100



H. 0







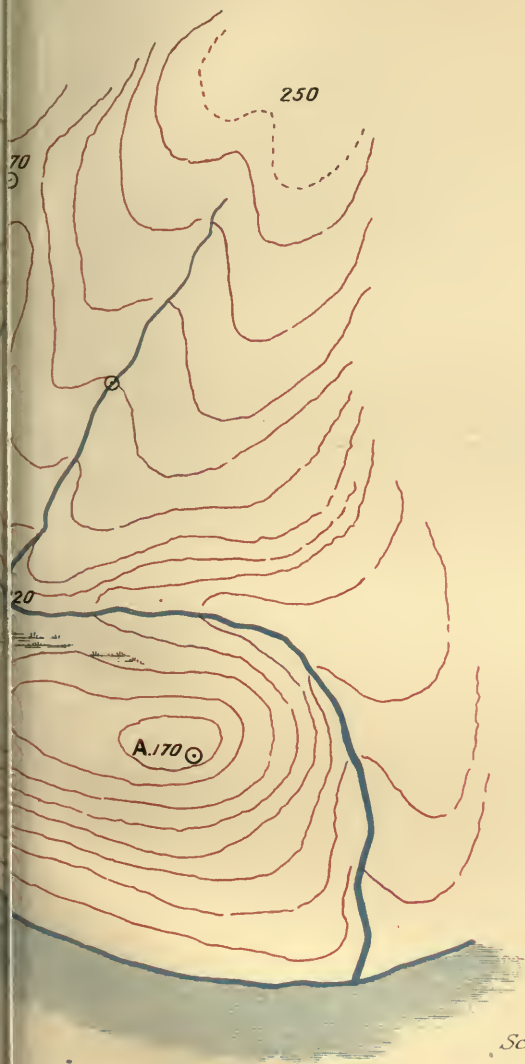




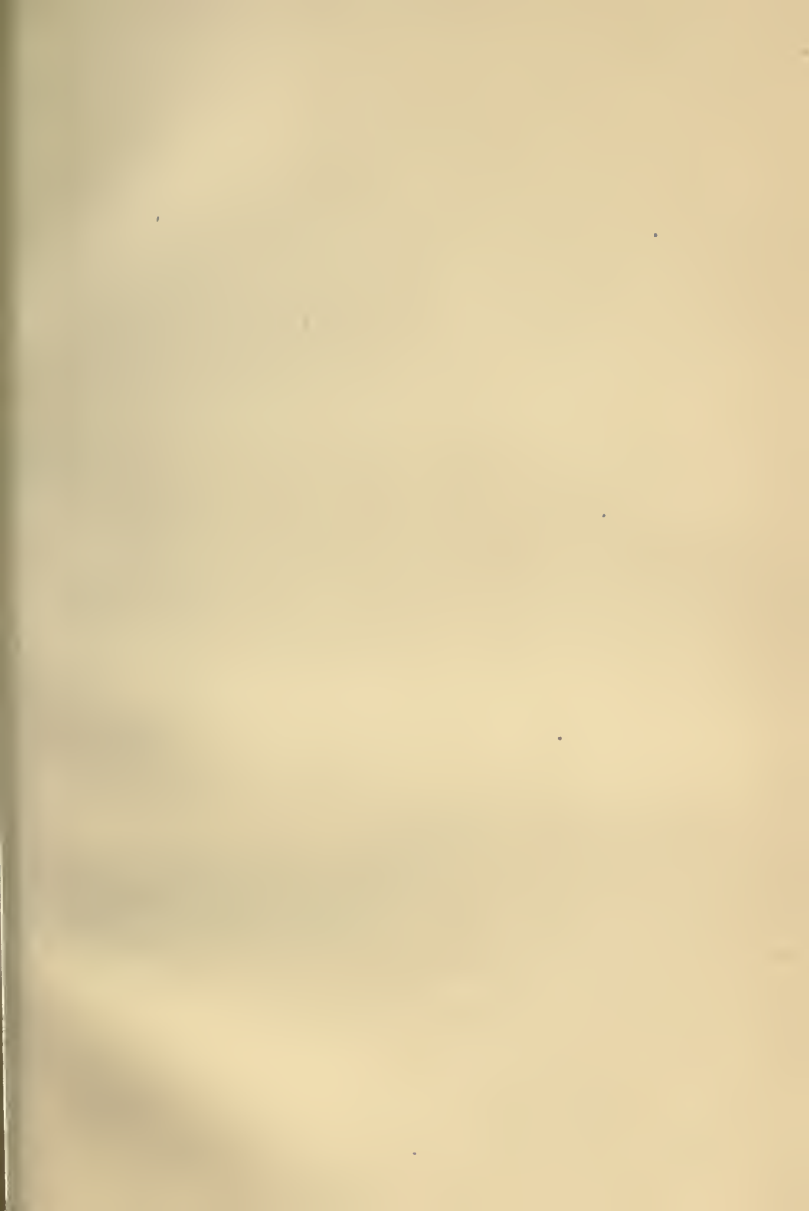
Scale. 10000. VI. 20 feet.

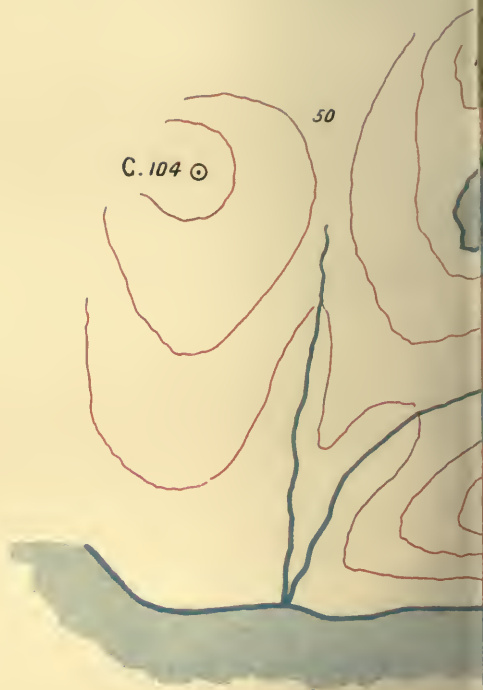






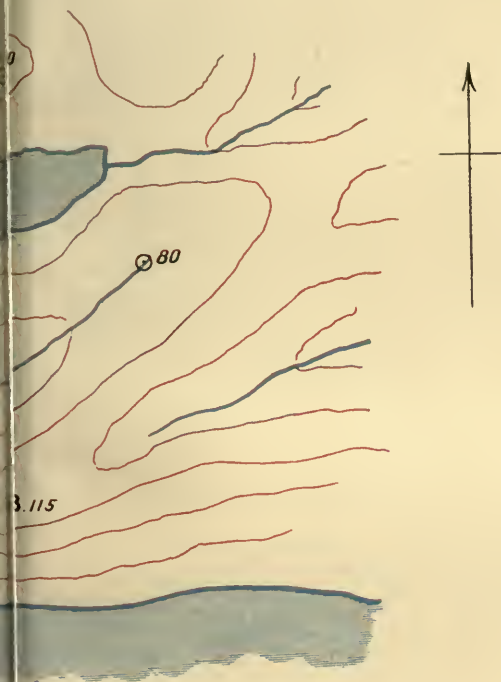
Scale. $\frac{1}{10360}$. VI 20 feet.



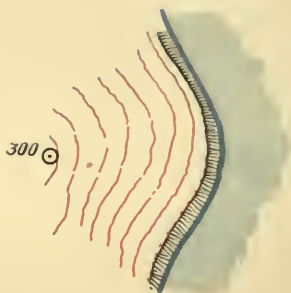


C. 104

50

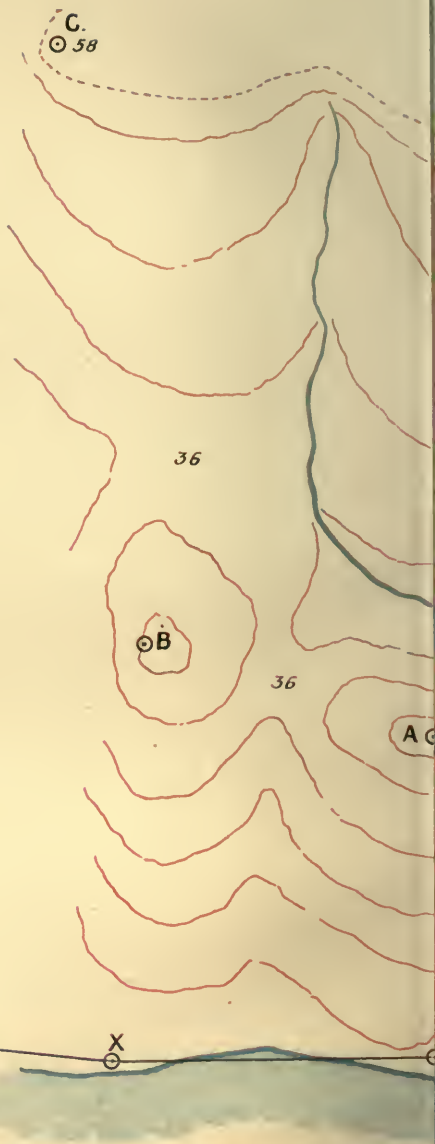


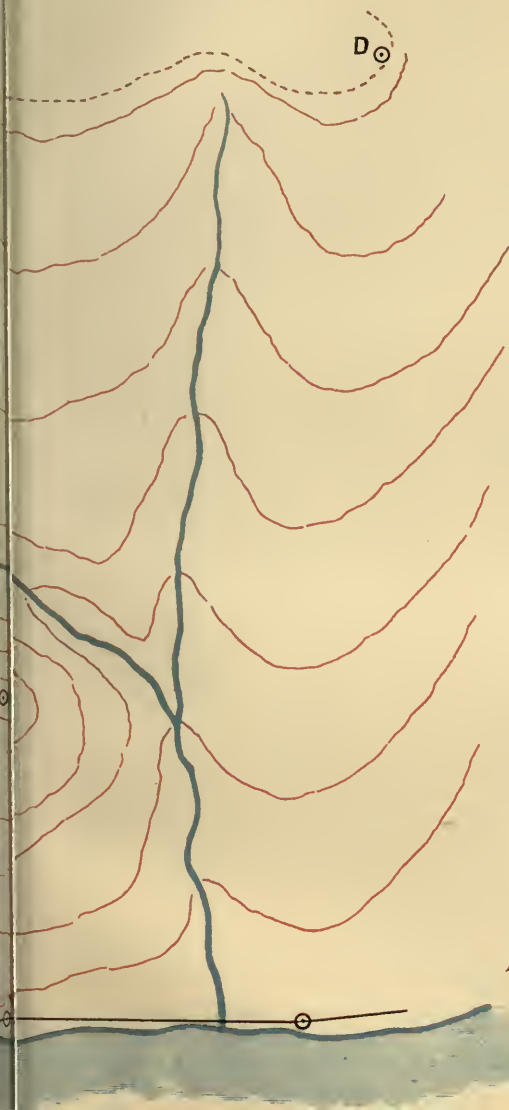
Scale. $\frac{1}{15840}$. VI. 30 feet.



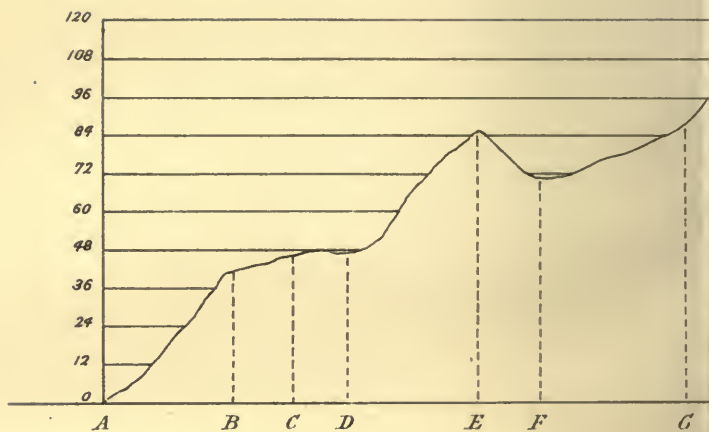
Scale. 15000. VI. 30 feet



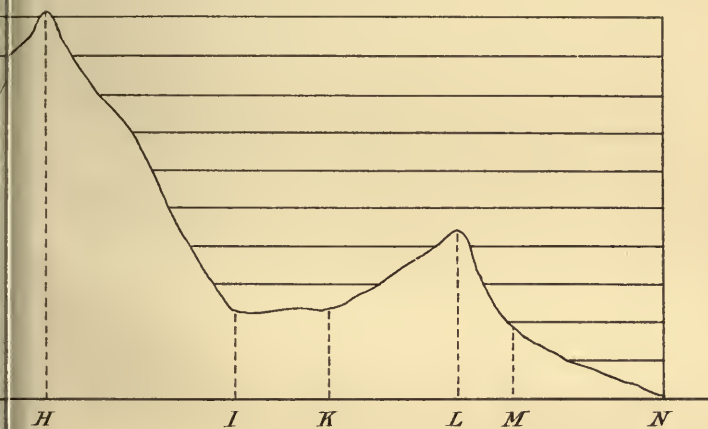




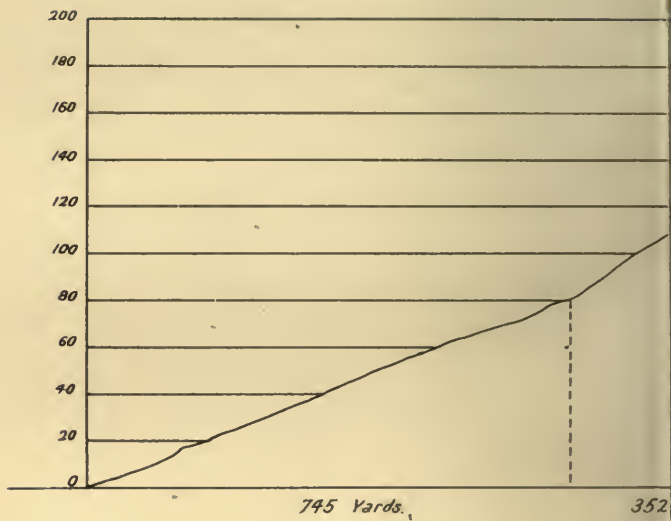
Scale. $\frac{1}{4224}$. VI. 8 feet.



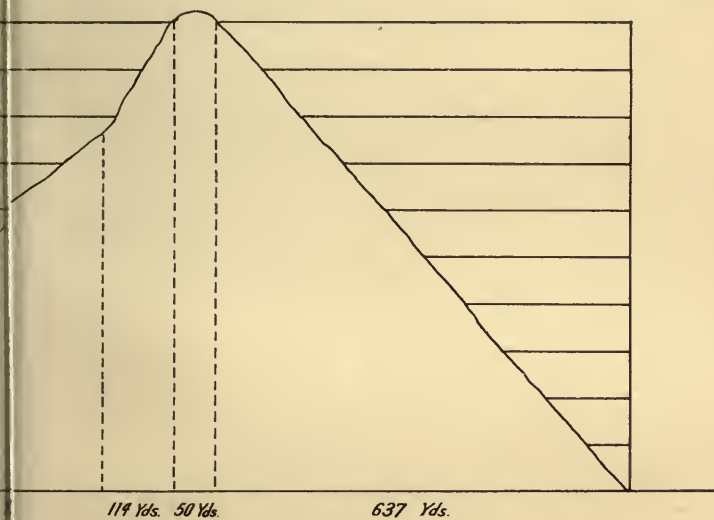
Scale. $\frac{1}{10560}$.



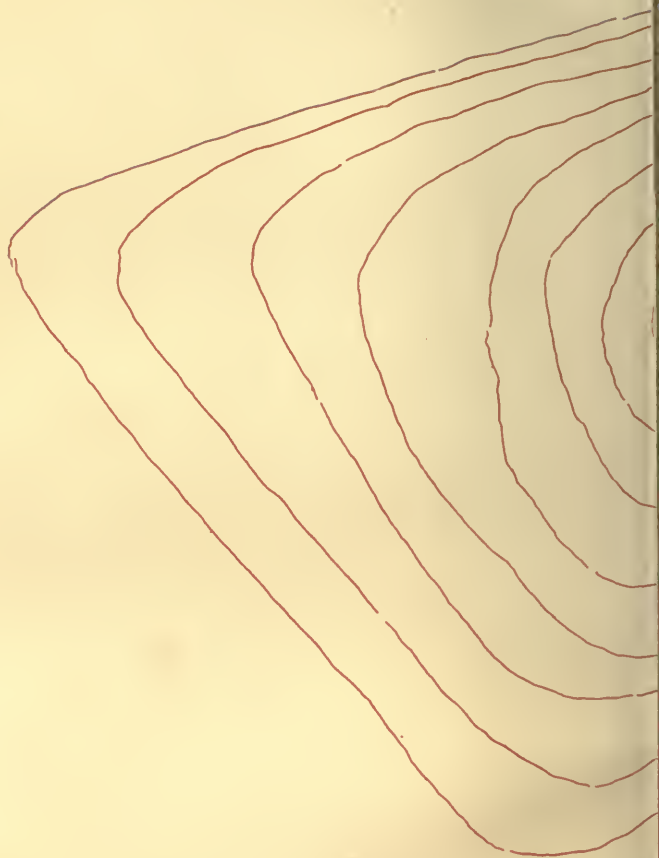
about $\frac{1}{3}$ inch.



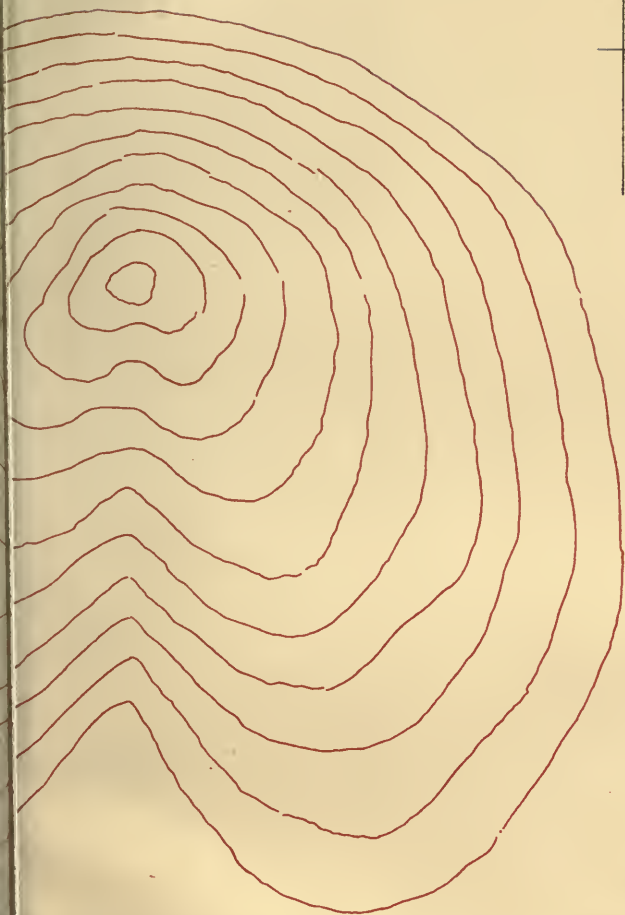
Scale $\frac{1}{10560}$. Con



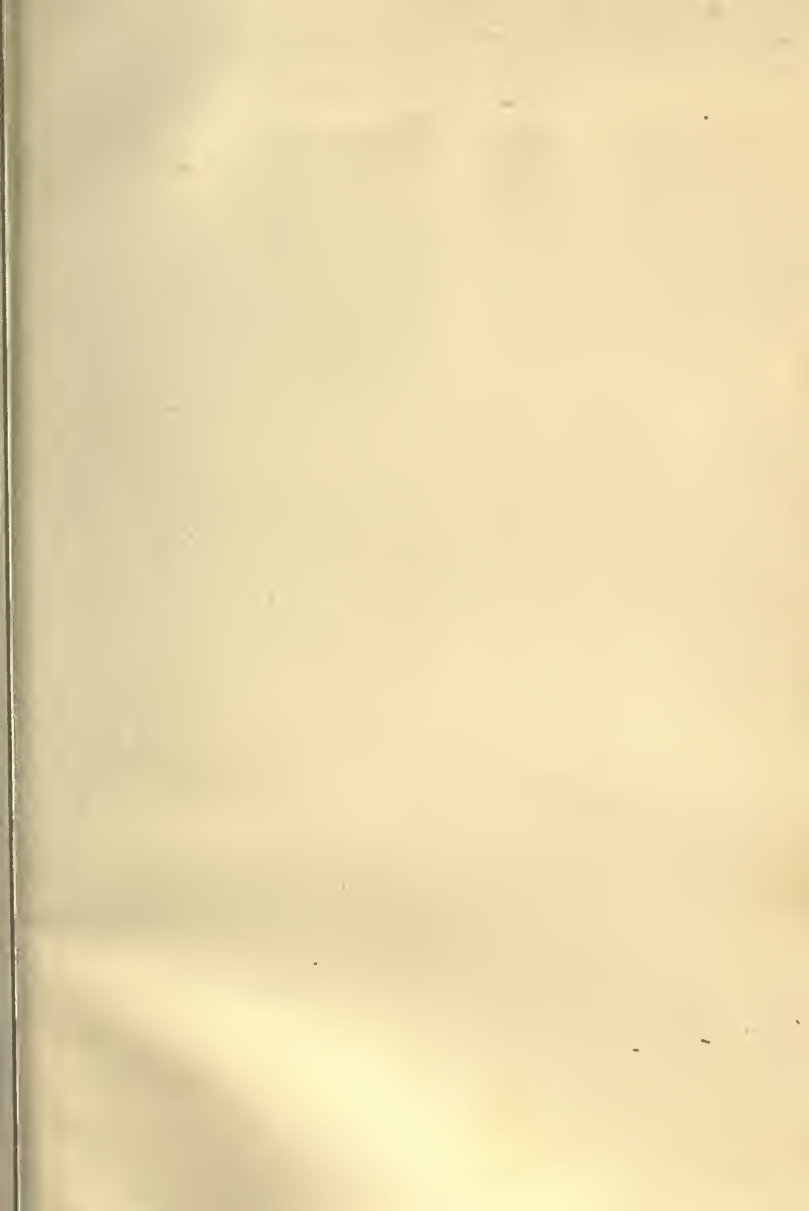
hrs .25 of an inch.



Scale. $\frac{1}{10360}$. VI 20 feet







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